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April 20, 2004

Mr. Allen Wojtas
Work Assignment Manager
U.S. EPA Region 5, DM-7J
77 W. Jackson Boulevard
Chicago, IL 60604

Reference: EPA Contract No. 68-W-02-019; EPA Work Assignment No. R05902; Corrective Action Support; USS Lead Refinery, Inc., East Chicago, IN; EPA ID No. IND047030226; DRAFT Characterization of Metals in Soil in the Vicinity of the USS Lead Site, East Chicago, Indiana; Task 02 Deliverable

Dear Mr. Wojtas:

Enclosed please find TechLaw s DRAFT Characterization of Metals in Soil in the Vicinity of the USS Lead Site, East Chicago, Indiana. For your convenience, this report has been provided in WordPerfect format and provided directly to Ms. Mirtha Capiro, the EPA Technical Lead for this project.

TechLaw has prepared this draft version of this report at the request of the EPA Technical Lead to meet certain project objectives. TechLaw is continuing to evaluate the available data, review relevant literature, and finalize figures and tables for this report. TechLaw will discuss the contents of this Draft report with EPA. A Final version of this report will be submitted with 14 days after receiving comments on this Draft version of the report.

If you have any questions, or wish to further discuss these comments, please feel free to contact either myself, Mr. Todd Quillen at (617)720-0320 x124 or Ms. Kristi Pawski at (312) 345-8963.

Sincerely,

John G. Koehnen
Regional Project Manager

cc: F. Norling, U.S. EPA Region 5 RPO (w/out att)
M. Capiro, U.S. EPA Region 5
B. Smith/Central Files
K. Pawski
Chicago Central Files

DRAFT CHARACTERIZATION OF LEAD AND OTHER METALS IN SOIL IN THE VICINITY OF THE USS LEAD SITE, EAST CHICAGO, INDIANA

USS LEAD REFINERY, INC.
EAST CHICAGO, IN
EPA ID NO. IND047030226

Submitted to:

Mr. Allen Wojtas
EPA Work Assignment Manager
U.S. Environmental Protection Agency
Region 5 DE-9J
77 W. Jackson
Chicago, Illinois 60604

Submitted by:

TechLaw, Inc.
105 West Madison Street, Suite 900
Chicago, Illinois 60602

EPA Work Assignment:	**R05902**
Contract No.:	**68-W-02-019**
EPA WAM:	**Allen Wojtas**
Telephone No.:	**312/886-6194**
EPA TA:	**Mirtha Capiro**
Telephone No.:	**312/886-7567**
TechLaw WAM:	**Kristi Pawski**
Telephone No.:	**312/345-8963**

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USS LEAD REFINERY, INC.
EAST CHICAGO, INDIANA

DRAFT CHARACTERIZATION OF METALS IN SOIL IN THE VICINITY OF THE USS LEAD SITE, EAST CHICAGO, INDIANA

1.0 INTRODUCTION

The purpose of this report is to present analytical results for samples collected on- and off-site of the USS Lead Refinery (USS Lead) Site, a former lead smelting and refining operation, in East Chicago, Indiana. On-site samples were collected from undisturbed areas in an attempt to understand characteristics of contamination associated with the USS Lead site. Off-site samples were collected from areas that were not visibly disturbed in order to understand the concentrations and characteristics of lead and other metals.

Analytical results from the collected samples were evaluated to ascertain whether airborne contamination related to the USS Lead facility that warrants further investigation is present within the study area. The analytical results from off-site areas was compared to analytical results from the USS Lead site to determine whether there is presence of USS Lead contamination in the off-site areas.

TechLaw, Inc. received technical direction from the U.S. EPA Region 5, on May 9, 2002 to conduct split sampling and provide analytical assistance in support of the Modified RCRA Facility Investigation (MRFI) activities at the USS Lead site. Chemical analysis of samples was conducted by a TechLaw Team laboratory, American Analytical Testing Services (AATS) using inductively coupled plasma/mass spectrometry (ICP/MS) methods. Electron microprobe analysis (EMPA) was conducted by the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado in Boulder. This report describes the sample collection, preparation, presents the results of the analysis and provides an evaluation of the results.

2.0 SITE DESCRIPTION AND HISTORY

The USS Lead site is located in East Chicago, Lake County, Indiana (Figure 2-1). The area of the site is approximately 79 acres. A 14 acre Corrective Action Management Unit (CAMU) and other disturbed areas occupy approximately 25 acres of the site. The CAMU is present in the eastern portion of an upland area of the site. The CAMU represents an artificial rise in topography (i.e., a relatively expansive mound) and is currently covered with a 3-foot deep, native sand cover and an engineered cap. The cover has been planted with native vegetation. The CAMU is adjacent to a developed roadway to the east (Kennedy Avenue), an open water body (created during excavation of the former slag pile) immediately to the south, and low-lying wetland areas to the south and southwest. Upland areas occur to the north, and a combined

upland and remnant dune swale habitat occurs immediately to the west and northwest.

The USS Lead site lies in the Calumet Lacustrine Plain. The Calumet Lacustrine Plain is characterized by a flat to gently undulating surface that slopes gently to Lake Michigan (USGS, 2001). The sands that are common in the upper portion of the Calumet Lacustrine Plain are dune, beach, and lacustrine sediments that may contain thin, discontinuous layers of muck, peat, and organic material. Site specific geology has been characterized in the Draft Final MRFI Report (USS Lead, 2004) and other site documents. Borings at the USS Lead site indicate that sand is present from ground surface to a depth of 25 feet. The sands are underlain by a clay-rich unit described as the Wadsworth Till. Generally there are three soil types present in the vicinity of the USS Lead Site: UR (Urban Land), CA (Carlisle Muck [for example, wetland areas in southwest portion of the site]), and OkB (Oakville-Tawas complex [for example, upland areas in western portion of the site]).

USS Lead was a former secondary lead smelter and reprocessor of lead-acid batteries. The facility was a generator and owner/operator of a treatment and storage facility and disposed of hazardous wastes (EPA, 1993). From approximately 1906 to 1920 copper smelting operations took place at the site. From 1920 to approximately 1973 USS Lead conducted primary lead smelting operations including lead refining to produce high quality lead which was free of bismuth. It was noted that the treatment of bismuth dross yielded metals containing gold, silver, and metals of the platinum group. In 1973 USS Lead converted their operations to secondary lead smelting. The secondary refinery operations included: battery breaking with tank treatment of spent battery acid at a rate of 16,000 gallons per day; sulfuric acid treatment with storage of calcium sulfate sludge in a waste pile and generated at 1.5 tons per day; baghouse dust collection with storage in on-site waste piles of up to 8,000 tons of baghouse flue dust; and blast furnace slag disposal, which was deposited in the wetland adjacent to the facility (EPA, 1993). The process area buildings at USS Lead are shown in Figure 2-2. Secondary lead recovery operations ceased in December 1985.

Interim Stabilization Measures have been implemented at the site pursuant to the U.S. EPA AOC dated November 18, 1993 (EPA, 1993), and the facility has been working to complete IDEM closure requirements as follows: remove lead slag pile; remove battery chips; remove contaminated soils above IDEM human health Industrial lead levels; characterize and remove contaminated sediments within the canal; conduct closure for former hazardous waste management units; and plug sewer and waterlines from the former process area of the facility. Contaminated materials were placed in the onsite CAMU. The CAMU has been covered with an engineered cap and the facility has been pumping groundwater out of the CAMU in attempt to achieve an inward hydraulic gradient.

Clean up at the site has been conducted as a series of removals. While removals were conducted in accordance with an approved ISM Work Plan, the removal activities also included many decisions based on field observations and were not necessarily conducted with EPA or IDEM oversight. The current site conditions are described by the facility in the *Draft Final Modified*

RCRA Facility Investigation (MRFI) Report (USS Lead, 2004).

The USS Lead site vicinity has historically supported a variety of industries. In addition to the USS Lead smelting operation, some other industrial operations apparently also managed lead. For example, immediately east of the USS Lead site, across Kennedy Avenue, is a former Dupont site which reportedly manufactured the pesticide lead arsenate (Dupont Report, ####). Northwest of the USS Lead site, west of Gladiola Street and north of 151st Street, two smelter operations reportedly managed lead and other metals (USS Lead, 2004). A figure from the USS Lead MRFI Report (Figure 23, Examples of Historic Contamination Sources Proximal to USS Lead Refinery, USS Lead, 2004) presents data attributed to a 1930 Sanborn Map and identifies the operations as Anaconda Lead Smelter and International Lead Refining Company. A figure prepared by USS Lead is included in this report as Figure 2-1, for reference. A wind rose describing the wind conditions in the vicinity of the USS Lead site is presented as Figure 2-2.

3.0 SAMPLE COLLECTION

The samples considered in this study primarily were collected through two sampling events which took place in the summer of 2003. On-site samples, collected from within the USS Lead property boundaries, were split samples collected by TechLaw on July 9, 2003. Off-site samples, collected from residential and other locations not on USS Lead property, were collected by an EPA field team in July and August 2003.

A third set of samples also will be discussed in this report. These samples were collected from USS Lead, Kennedy Avenue right-of-way, and Dupont property by TechLaw during a field event in 2002. Each of these field events is described in this section.

3.1 On-Site Samples

TechLaw conducted field oversight and split sampling activities at the USS Lead Site during Modified RCRA Facility Investigation (MRFI) field activities on July 8 and 9, 2003. TechLaw observed sampling activities at 24 locations on-site. On July 9, 2003, Ms. Amie Motsinger of TechLaw collected split soil samples at 14 of these locations. Soil sampling activities were conducted in accordance with TechLaw s approved Surface Soil Sampling and Analysis Plan, dated July 8, 2003, and TechLaw s approved EPA Region 5 Generic Quality Assurance Program Plan (QAPP). Sample collection included the collection of all appropriate quality control (QC) samples.

The on-site samples analyzed for this study were collected from the zero- to six- inch interval. All samples were collected by USS Lead representatives in accordance with the *Revised MRFI Work Plan Addendum, Revision 2*, dated May 30, 2003 (USS Lead, 2003). The samples were collected using a stainless steel spoon and bowl. The samples were homogenized and the sample containers for USS Lead and TechLaw were filled. Multiple sample containers were filled for

TechLaw to allow split samples to be sent to multiple locations for analysis. The holes were filled in after sample collection. The split samples were maintained within TechLaw s custody at all times until they were shipped to the laboratories.

Of the 15 samples that were collected, only eight were selected for analysis in this study. USS Lead preliminary analytical results from the USS Lead aliquot of the split samples were reviewed by EPA and TechLaw to assist with the decision regarding which of the 15 samples to analyze. The eight samples that were selected for analysis were selected based on metals concentrations and location. The samples were shipped to AATS and the Laboratory for Environmental and Geological Studies at the University of Colorado in Boulder.

3.2 Off-Site Samples

Off-site samples were collected during the period from July 23, 2003 through August 21, 2003. These samples were collected in accordance with the *Quality Assurance Project Plan, USS Lead Refinery Inc. and Vicinity* (Project QAPP), dated July 2003 (EPA, 2003a) and the *USS Lead Refinery Inc. and Vicinity, East Chicago, Indiana, Sampling and Analysis Plan* (Off-site SAP) dated July 2003 (EPA, 2003b). The collection and XRF analysis of these samples are described in the *Report on X-ray Fluorescence Field Study of Selected Properties in Vicinity of Former USS Lead Refinery Facility, East Chicago, Indiana* (Off-site Report), dated November 2003 (EPA, 2003c). The description of the sampling presented here is taken from the Off-site Report.

As described in the Off-site Report, soil sampling for X-ray fluorescence (XRF) analysis was completed at 83 locations. These locations are shown in Figure 3-2. Of these 83 locations only 20 samples were subjected to laboratory analysis. As described below, several factors, including location and XRF results, were considered in the selection of samples to be subjected to laboratory analysis. Each of the 83 location was assigned an x identifier. The locations which were selected for laboratory analysis were also assigned an s identifier in addition to the x identifier.

All samples were collected by either Michael Mikulka or Mirtha Capiro of U.S. EPA, or Mike Sickels of IDEM using the procedures identified in the SAP. Sample locations had not been identified in the QAPP or SAP since sample collection was dependent upon individual property owners granting access. Access was sought prior to or concurrent with each day s sampling activities, and property owners granting access usually had their properties sampled the same day or the following day, with some exceptions.

Soil for screening and sample collection was composited from a residential house yard or public area (vacant lot, park, ball diamond) using a 5 point composite in accordance with procedures described in EPA Guidance Document *Superfund Lead-Contaminated Residential Sites Handbook*, OSWER 9285.7-50 (Draft) October 2002; or, for industrial property, from a one (1) square meter area (m^2) area. Typically, soil was scraped from upper 1-2 inches of the target areas using a pre-cleaned disposable plastic scoop or spoon, then placed in a pre-cleaned disposable

plastic bowl or other container for homogenization. If the target area was covered with grass, the grass was cut away with a knife with a stainless steel blade and pulled back to expose the soil for sample collection. At industrial properties, a stainless steel shovel was used as necessary to clear tall grass from the areas where the composite sample was collected. Approximately 4 scoops of soil were obtained from each point in the 5-point composite, for a total of 20 scoops of soil. Upon collection of the soil sample, the grass was replaced and tamped down. The bowl of sample material was transported back to the processing area, where grass, roots and rocks were removed manually (or in some cases with a Number 8 mesh stainless steel sieve), and the bowl labeled and covered with foil. If the soil was wet, the foil was pulled back and the bowl placed in the sun to allow the soil to air dry, while mixing periodically to allow drier surface soil to mix with wetter soil. Once the soil was sufficiently dry (depending on conditions, up to 4 hours drying time on some samples), 4-5 scoops of the sample were placed in a re-sealable 1 quart plastic bag for XRF analysis. All XRF screening was conducted on a bagged sample, with XRF instrument readings expressed in parts per million (ppm). After screening, it was determined by the Field Project Manager in conjunction with the Project Manager whether to proceed with sample collection for laboratory analysis based on the screening result. Initially, the plan was to collect samples for laboratory analysis from all locations where the Pb XRF screening result exceeded 400 ppm. However, based on the first few samples screened (all exceeding 400 ppm Pb) it was determined that the number of samples sent to the laboratory would far exceed the initial target and therefore the allotted budget. Therefore, sample collection was cut back to meet the minimum requirements of the study based on the SAP (confirmation for at least 10% of samples screened, and at least 1 per field day) and also provide sufficient information to ascertain possible Pb sources based on proximity to both USS Lead and other potential industrial sources. Sample collection also included field duplicate collections from locations S03 & S07 (samples D03 & D07), and matrix spike/matrix spike duplicate (MS/MSD) sample collection from location S07 (sample M07).

Upon completion of sample processing, if soil screening levels for lead exceeded 400 ppm, and the sample location also met other goals of the project, then sample bottles were prepared from the sample bowl. Section 3.2 of the Off-site SAP, Selection of Screening and Sampling locations, explains the rationale for proceeding with sample collection for consideration for laboratory analysis. Upon filling and labeling, the sample bottles were placed in an iced cooler within the vehicle used for equipment storage and remained within the custody of the processing personnel.

Re-sampling was conducted at certain XRF screening locations that were not originally selected by the FPM for sample collection for laboratory analysis, but were later determined by the PM (after review of all XRF data) to be appropriate locations for sample collection, mainly to attempt to confirm the source of the Pb. Locations X07 and X08 were re-sampled on August 12, 2003, and location X20 was resampled on August 21, 2003, by Mirtha Capiro of USEPA. Re-sampling included 5 point composite sampling and homogenization as per the SAP, but did not include XRF screening. As such, the laboratory results from these samples will not be directly comparable to the XRF results, as they are not from the same sample. These 3 samples should be

considered co-located samples to the samples which were screened by the XRF.

The samples were maintained under EPA custody until custody was transferred to TechLaw immediately prior to TechLaw shipping the samples. The samples were shipped to AATS and the Laboratory for Environmental and Geological Studies at the University of Colorado in Boulder.

3.3 On- and Off-Site Samples Collected in August 2002

On August 15, 2002, TechLaw conducted sampling at six locations in the vicinity of the USS Site. The sample locations may be seen on Figure 3-5. All samples were surface samples collected from an interval of 0-6 inches below ground surface (bgs) with the exception of sample SS-02 which was collected from a depth interval of 10-16 inches bgs. Because only a limited number of samples were proposed, TechLaw collected material from the specified sampling interval from three points within a one meter area. This approach was taken to minimize the influence of potential variability in the distribution of anthropogenic lead at each location (i.e., slag versus native sand contaminated with air-deposited material).

- Sample SS-01 was collected from the northwest face of a paleo-dune immediately west of an area that had historically been used to store uncontrolled piles of baghouse dust. The sample was dark brown, fine to medium grained sand with some organic material.

- Sample SS-02 was collected at depth from an on-site area to evaluate levels of metals in soils that were not significantly impacted by anthropogenic activities. They did not appear to be disturbed by operations at the site based on site reconnaissance and reviews of historical aerial photographs. The surface interval was not considered because of expected impacts from aerial deposition of lead from the site. The sample was light brown, fine to medium grained sand with minor organic material.

- Sample SS-03 was collected from a portion of the wetlands near the former slag pile. The presence of a thick (> 1 foot) vegetative mat in the area suggests that the area has not recently been a fluvial channel. The sample did not appear to contain mineral material larger than sand-sized particles suggesting the sample did not contain appreciable amounts of slag. The sample was grey, wet, silt and sand with abundant organic material.

- Sample SS-04 (and duplicate sample SS-07) was collected from along Kennedy Avenue, downwind from the former blast furnace location. The sample was brown, fine to medium grained sand with some larger particles (potentially slag).

- Sample SS-05 was collected from a location downwind of the USS Lead site on Dupont Property. The location was selected because previous analytical results suggested that elevated levels of lead were found in the area. Although TechLaw strived to find a sample location that could be considered native sand potentially impacted by aerial deposition, the sample location

was found to contain abundant slag under a thin layer (< 1 inch) of sand. The sample could be characterized as abundant slag with some sand. The sample location for SS-05 was not selected based on any unusual site-specific characteristics (i.e., not selected based on vegetative stress, slag was present across most of this area).

- Sample SS-06 was also collected from a location downwind of the USS Lead site on Dupont Property. The location was selected away from the SS-05 area in attempt to characterize a more generally representative downwind area (i.e., not near the previously identified elevated concentrations of lead near location SS-05). The sample was collected from what appeared to be a sandy area between two medium-sized trees (4 to 5 feet apart, approximately 1 foot diameter trunks); using the rationale that the trees had been present in the area for a while and the area might contain more native sand and less slag than the surrounding, open areas. The sample was found to be abundant in slag with some sand.

All samples were collected using the same method. A disposable plastic or steel spoon was used to clear away leaf litter and debris. A second disposable plastic or steel spoon was then used to scoop soil into a plastic bowl. The soil was then homogenized, quartered, and transferred into the sample containers (eight-ounce unpreserved glass jars with teflon-lined lids). Four sample containers were filled from each sample location. Large organic material, rock, and slag were avoided when selecting the sample locations, and these particles were removed from the bowl or avoided when placing the soils into the sample containers. The samples were maintained under TechLaw s custody during additional sampling activities and immediately placed into a cooler with ice when the field team returned to the locked vehicles. The samples were shipped to Southwest Laboratory in Broken Arrow, Oklahoma (SWOK). Southwest Laboratory provided the samples to their partner laboratory, AATS, to conduct the analyses.

4.0 ANALYTICAL METHODS

4.1 On- and Off-Site Samples Collected in 2003

The on-site and off-site samples collected in July and August 2003 were all subjected to similar analyses. These analyses are summarized in Table 4-1. A description of the analyses is presented here.

4.1.1 Preparation/Sieving

A portion of the samples sent to AATS were dry-sieved through a 150 micron screen. Following sieving both a fine fraction (<150 micron) and a residual fraction (>150 micron) were available for analysis. A bulk fraction, which was not sieved, was also available for analysis.

Samples sent to LEGS for EMPA analysis were not sieved. EMPA preparation techniques such as mixing with epoxy resin, grinding, and polishing are described in the LEGS Lead Speciation

Lab Report (LEGS, 2003) as well as in the EMPA Standard Operating Procedure available on the LEGS website at http://www.colorado.edu/geolsci/legs/speciation1.html.

4.1.2 X-Ray Fluorescence Analysis

X-ray Fluorescence analysis was conducted on the off-site samples by EPA. The methods are described in the Off-Site Report (EPA, 2003).

4.1.3 Quantitative Analysis

The quantitative analysis described in this report was conducted in accordance with EPA SW-846 Method 6020. Data was reported for 16 metals including 11 metals recommended for analysis under Method 6020 (antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, nickel, silver, and zinc) as well as calcium, iron, selenium, tin, and zircon. Contract Laboratory Program (CLP)-like data packages were presented for these analyses.

4.1.4 Semiquantitative Analysis

Semiquantitative analyses were conducted using ICP/MS techniques similar to those used for the quantitative analysis. Data from raw data scans (integrated counts per second for each mass) were provided to TechLaw without quantification or semiquantification. Scans were conducted from the same prepared solutions that were used in the quantitative analysis (including the same standards, blanks, internal standards, and QC samples). Integrated counts per second were provided for every mass for m/z ratio from 5 to 238, but ignoring any masses that would have caused harm to the instrument (i.e., 12, 14, 16, 18, 28, 32, 40, 80, etc.). The only additional QC sample that was run was NIST 981 common lead standard at the beginning and end of the scan run, at a concentration in the range of the samples. TechLaw received the data in electronic format and calculated concentrations for all of the masses that were reported.

The semiquantitative scans provided concentration data for the same elements that were reported for the quantitative analysis. In addition, concentrations were derived for other elements for which standards were run yet the concentrations were not previously determined through the quantitative analysis. Lastly, additional concentration data was calculated for elements for which no standards were run.

4.1.5 Lead Isotope Analysis

Lead isotope analysis was conducted as part of the semiquantitative analysis. Integrated counts per second were requested by TechLaw for each of the four isotopes of lead (i.e., 204, 207, 207, and 208). As requested, the NIST 981 lead standard was run at the beginning and end of each scan run.

To be discussed: only one integration versus three in 2002. Also, mass bias correction factor

applied and instrument correction factor applied.

4.1.6 Electron Microprobe Analysis

The electron microprobe analysis (EMPA) was conducted by Dr. John Drexler at the LEGS laboratory at the University of Colorado at Boulder. The Standard Operating Procedure for the EMPA analysis is available on the LEGS website at http://www.colorado.edu/geolsci/legs/speciation1.html. Generally, puck consisting of resin and several grams of sample is examined. Traverses are made across the sample at two different magnifications (i.e., 40 to 100X and then 300 to 600 X to identify the smallest, 1 to 2 micron phases). The operator attempts to count at least 100 particles per sample. If analysis becomes too time consuming then the operator spends only eight hours analyzing each sample.

For each sample, data is provided on the size and phase of each metallic particle that was included in the point count, frequency of occurrence of all lead-bearing phases, and the calculated relative mass of lead.

4.2 Samples Collected in 2002

The six samples that were collected in 2002 were sent to Southwest Laboratories of Oklahoma (SWOK). Because of the specific analyses that were requested by TechLaw, the samples were prepared and analyzed by AATS, similar to the on- and off-site samples. The samples were dry-sieved through a 150 micron screen. Quantitative analysis was conducted in accordance with EPA SW-846 Method 6020. In addition, a lead isotope scan was conducted using NIST standard 981.

5.0 RESULTS

5.1 Chemical Data

- Figures # and # present off-site XRF results.
- Figure # presents historical results collected from the vicinity of the USS Lead site (Note: poor control of sample interval leads to variations in data)
- Tables # and # present the quantitative and semiquantitative results.

5.2 Lead Isotope Data

Lead isotope values were calculated from the semiquantitative data. The values were plotted on coordinate systems with 208/206 ratios plotted on the Y axis and 207/206 ratios plotted on the X axis. These plots are presented as Figures # through #.

5.3 EMPA Results

The EMPA Report submitted by Dr. John Drexler is provided as Appendix B to this report. The point count data is primarily presented as frequency of occurrence (F) for each type of particle and relative lead mass (R) that may be assigned to each particle. Data on individual particles is also presented including the size and phase.

6.0 DISCUSSION

6.1 Chemical Data

TechLaw is continuing to evaluate trends related to the major and minor element chemical data. The following will be considered in the Final Report

- Scatter plots of many chemical pairs
- XRF Results presented in the Off-Site Report prepared by EPA (EPA, 2003). In the northeast quadrant of the study area (i.e., north of 149th street and east of Kennedy Avenue) the concentrations of lead in soil were generally lower than other portions of the study area with no XRF lead results exceeding 400 ppm.
- Trends in other historical sampling results
- The concentrations observed in the off-site samples collected by EPA are generally higher due to the sampling interval of 0 to 2 inches
- The elevated concentrations of lead in soil on the Dupont property near TechLaw samples SS-05 and SS-06 appear to be anomalously high relative to other concentrations proceeding away from the USS Lead site.

6.2 Lead Isotope Trends

The lead isotope data from the 2002 sampling displayed a wide range along the isotope distribution line. The ratios of 208/206 and 207/206 were plotted on a coordinate system. The isotope signatures of samples collected from the Dupont site had lower ratios than those samples collected from the USS Lead site. The higher ratios observed in the samples collected from the USS Lead site were more similar to common lead than the Dupont samples. The observation of higher 208/206 and 207/206 ratios in the USS Lead samples is interpreted to be a signature of the lead from the processing of batteries in the secondary smelting operations at the USS Lead site (i.e., many sources of lead in the batteries, mixing of these sources through the smelting process).

Although this common lead trend in the USS Lead samples, relative to the Dupont Samples, is not conclusive, it appeared to be bolstered by the observation that there was an observed shift, along the trend line, in some samples such that the fine fraction signature was closer to common lead than the bulk fraction. Generally, shift that are perpendicular to the trend line may be attributed to random precision factors while shifts along the trend line may result from differences in the samples. The common lead shift in the fine fraction appeared to support the

model that fine material in the study area may have been generated through the smelting process at USS Lead. Such material could have been transported by wind and deposited.

TechLaw continues to evaluate the results of the 2003 on- and off-site lead isotope data. Generally, the data does not show the range in distribution that was observed in the 2002 data. For example, the 207/206 ratio of the 2002 data ranges approximately from 0.77 to 0.86 while the 207/206 ratio of the 2003 data ranges approximately from 0.82 to 0.845.

Lead isotope data was plotted for samples S07 and M07. Because an MS/MSD was requested for sample M07, the sample was analyzed multiple times in the semiquantitative analysis. The spike solutions would be expected to have negligible effects on the isotope data. The plotted values for S07, M07, M07L, M07s, M07sd show a wide range in variability spanning approximately across 50% of the cloud of data from the 2003 lead isotope data. The variability observed within this single sample, along with the limited range along the trend line described above, appear to limit the conclusions that may be drawn from the 2003 isotope data.

Almost all of the 2003 lead isotope data plots within the range that was observed for the USS Lead, rather than Dupont, samples in the 2002 data. The isotope data from the on-site locations sampled in 2003 generally plotted closer, along the trend line, to common lead than the isotope data from the off-site locations sampled in 2003.

6.3 EMPA

The metal bearing phases that were identified by the EMPA analysis include a wide variety of compounds. An example of the application of EMPA for assessing the impacts of smelter emissions on a community is provided in *A Study On The Source Of Anomalous Lead and Arsenic Concentrations in Soils From the El Paso Community - El Paso, Texas*, dated June 5, 2003, (El Paso Report) prepared by Dr. John Drexler at the LEGS (Drexler, 2003). A copy of this El Paso Report included in this report in Appendix C. In the El Paso Report there is a discussion of the complexity related to assigning certain phases to certain processes or sources. For example, anglesite (PbSO4) may be from lead ore, lead flue dust, or lead-based paint, among other potential sources. However, it is useful to evaluate the observed phases in the broader context of the study. Factors such as frequency of occurrence and location may help assign a reasonable context to each phase.

No attempt was made in this study to apportion each phase detected in off-site samples. However, the suite of phases detected in on-site samples was considered along with other geochemical factors to present the relative lead mass data from the EMPA analysis in an illustrative manner. For example, anglesite was a dominant phase identified in the on-site sample TL-07. This phase had a frequency of occurrence of almost 30% and it was responsible for more than 90% of the lead in the sample. Sample location TL-07 was in the wetland south of the former slag pile. It seems reasonable to attribute the anglesite in this sample to USS Lead smelting operations rather than, for example, lead-based paint. Each of the phases detected in the

EMPA analysis has been presented in bar charts in an order designed to illustrate relative lead mass related to smelting or metallurgical processes, presented to the left portion of the bar charts, phases related to weathering and soil formation such as iron and manganese hydroxides, and phases related to anthropogenic sources such as paint and brass.

Although the presentation of the bar-chart figures do not apportion phases, a signature may be seen when reviewing on-site data relative to off-site data.

7.0 CONCLUSIONS

Chemical data indicates that soils in the vicinity of the USS Lead site have been impacted by a variety of industrial contaminants.

An evaluation of trends with respect to the known industrial sources in the vicinity of the study area in currently being conducted. The lowest concentrations of lead in soil in the study area, according

Lead isotope data from the 2002 sampling indicates that lead from the USS Lead site may have a distinct signature (i.e., more similar to common lead) than lead from the Dupont site.

The lead isotope data from the 2003 on- and off-site data does not display as much variation along the trend line as the 2002 data. However, in general terms it appears that the on-site lead isotope data from the 2003 sampling plots closer to common lead than the off-site lead isotope data. Further, the lead isotope signature of the off-site data is more similar to the 2002 USS Lead lead isotope signature than the 2002 Dupont lead isotope signature.

EMPA results suggests that a significant amount of the lead within the study area may be complexed with iron and manganese hydroxides. Many lead phases that result from smelting processes do not typically have high solubilities. However, due to their small particle sizes, and relatively large surface areas, it is possible that airborne particulates carried into the off-site areas contributed a significant amount of the lead that is observed in the soil forming phases.

9.0 REFERENCES

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(TS-PIC-92075), August 1992.

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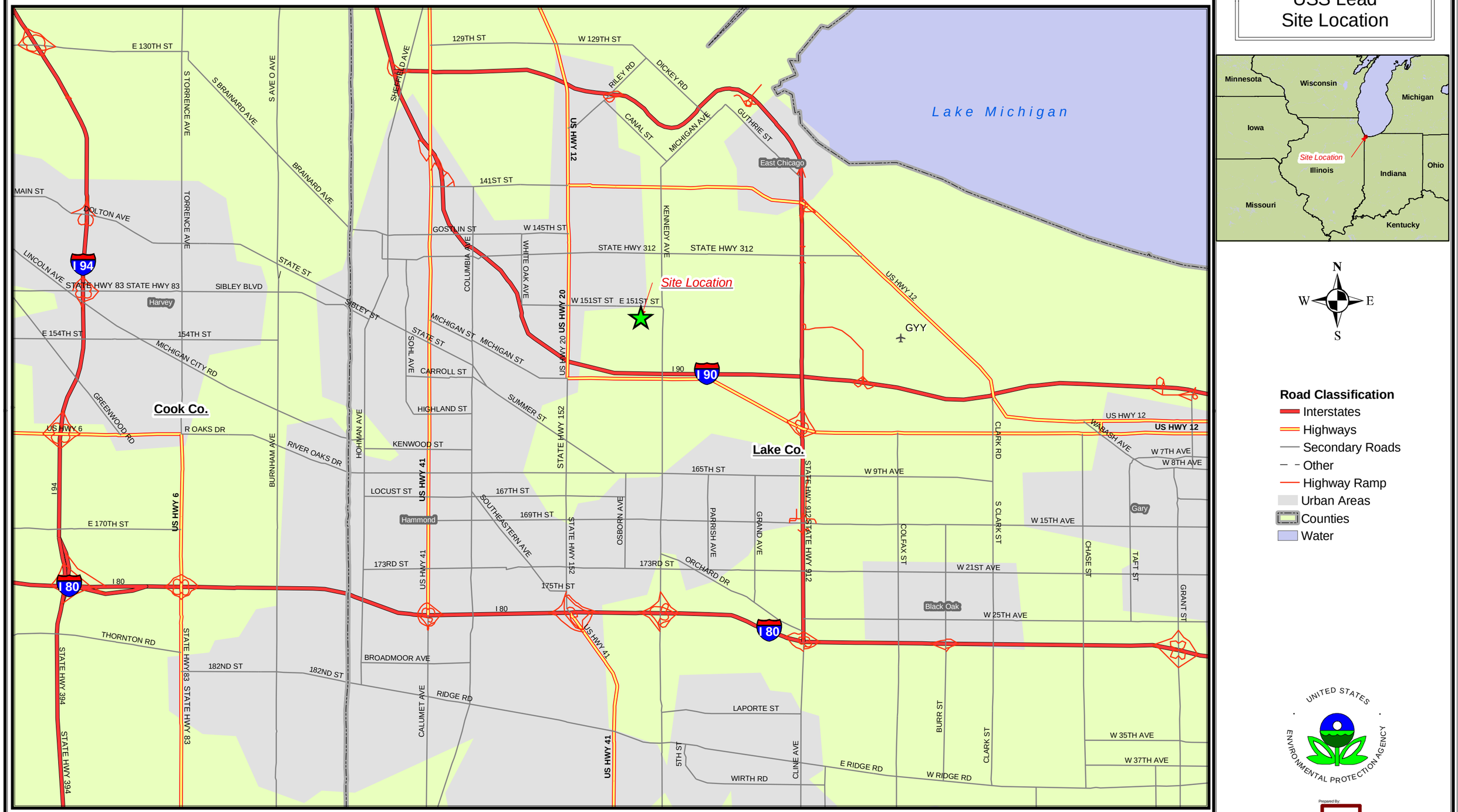
FIGURES

INTERNAL DRAFT - For Discussion Only

Figure 2-1

USS Lead Site Location



N
W E
S

Road Classification

- Interstates
- Highways
- Secondary Roads
- Other
- Highway Ramp
- Urban Areas
- Counties
- Water

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Prepared By:
TechLaw, Inc.

INTERNAL DRAFT - For Discussion Only

Figure 2-2
Process Area
Buildings at USS Lead
East Chicago
Lake County, Indiana

Stores Building
Tank House Building
Casting House
Club House
Fire House
Main Office
Maintenance Shop
Tellurium Plant
Change House
Laboratory
Pumphouse
Battery Breaker Building
Former Silver Refinery
Baghouse
Stack
Mixed Metals Building
Blast Furnace Building
Kennedy Ave.

N
W E
S

Note:
Aerial Date 19860324

Property Boundary
Facilities

15 7.5 0 15 Meters
50 25 0 50 Feet

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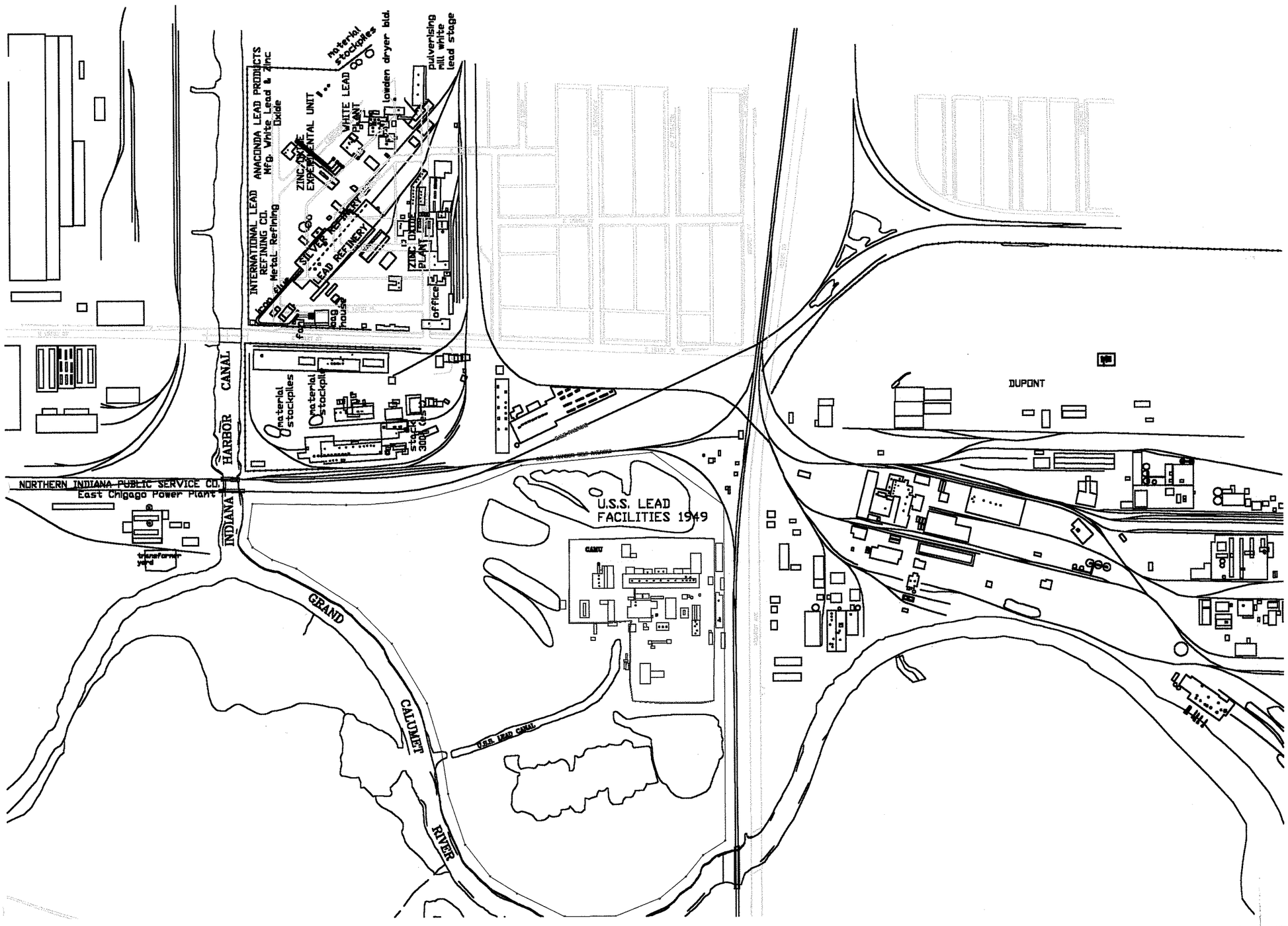


LEGEND

- RAILROAD TRACKS
- U.S.S. LEAD PROPERTY BOUNDARY
- WATER BODY
- VENTS
- VENTS
- EXHAUST STACKS
- EXHAUST STACKS

SOURCE DATA:

ALL BUILDING OUTLINES ARE FROM 1949 AERIAL PHOTOGRAPH WITH THE EXCEPTION OF NIPSCO POWER PLANT WHICH IS FROM 1930 SANBORN MAP

INTERNATIONAL LEAD REFINING CO. & ANACONDA BUILDING NOMENCLATURE IS FROM 1930 SANBORN MAP

NORTH

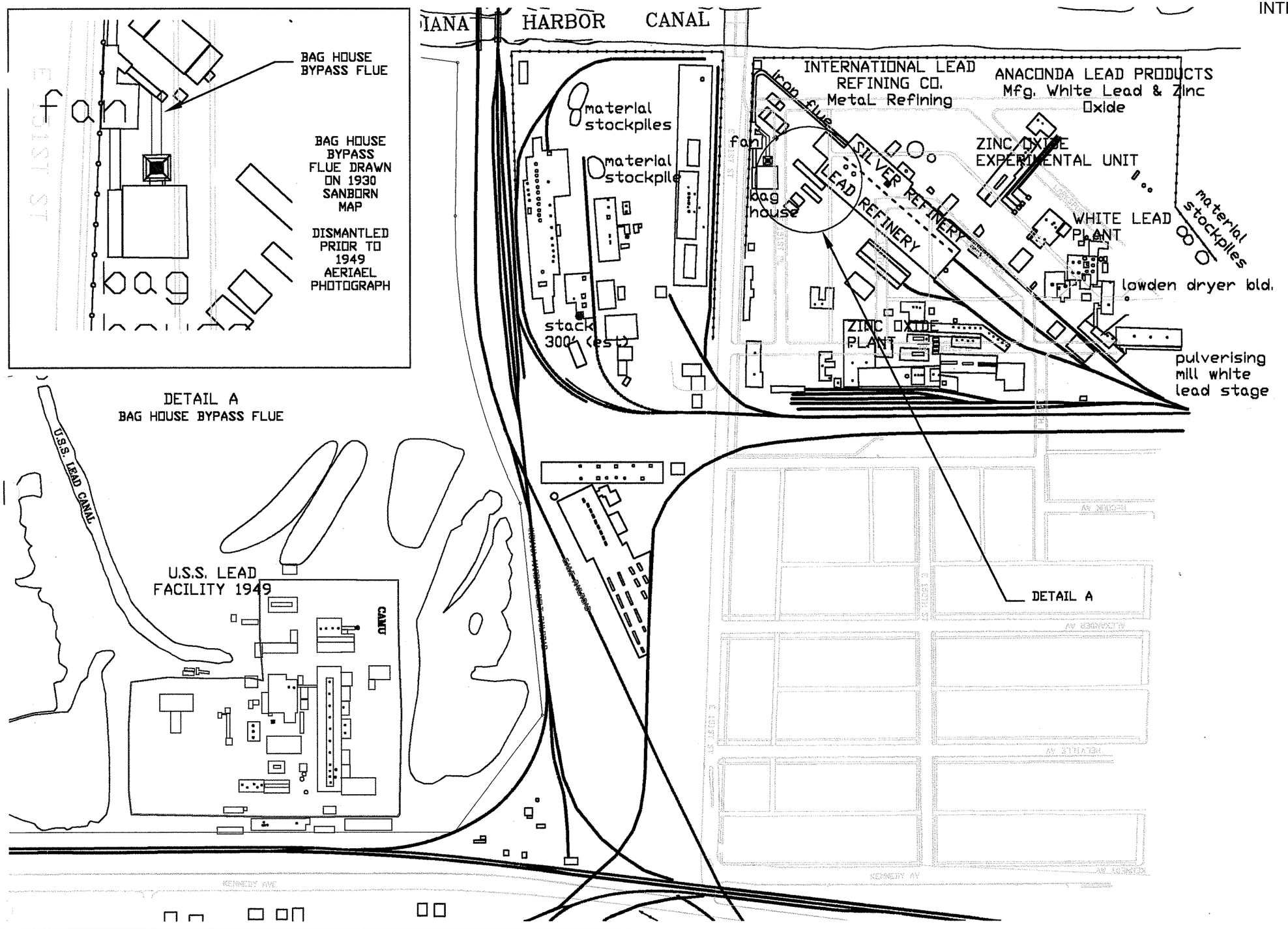
0 250' 500'

SCALE
1" = 500'

DATE: 7/21/2003 DRAWN BY: CSM CHECKED BY: SHEET OF	ENVIRONMENTAL DAI	Geochemical Solutions Environmental Sampling, Remediation & Compliance	U.S.S. LEAD REFINERY INC. 5300 KENNEDY AVENUE EAST CHICAGO, INDIANA	EXAMPLES OF HISTORIC CONTAMINATION SOURCES PROXIMAL TO U.S.S. LEAD 1930 & 1949	FIGURE A

INTERNAL DRAFT - For Discussio Only

DETAIL A
BAG HOUSE BYPASS FLUE



LEGEND

- RAILROAD TRACKS
- U.S.S. LEAD PROPERTY BOUNDARY
- WATER BODY
- VENTS
- VENTS
- EXHAUST STACKS
- EXHAUST STACKS

NOTE:
1930 SANBORN MAP SHOWED TWO STACKS ON LEAD REFINERY BUILDING. THESE TWO STACKS ARE NOT PRESENT ON THE 1949 AERIEL PHOTOGRAPH.

SOURCE DATA:

BUILDING FOOTPRINTS FROM 1949 AERIAL PHOTOGRAPH

BUILDING NOMENCLATURE & COMPANY NAMES 1930 SANBORN MAP

NORTH

0' 300 600'

SCALE 1" = 300'

DATE: 7/21/2003 DRAWN BY: CSM CHECKED BY: SHEET OF	ENVIRONMENTAL DAI	Geochemical Solutions Environmental Sampling, Remediation & Compliance	U.S.S. LEAD REFINERY INC. 5300 KENNEDY AVENUE EAST CHICAGO, INDIANA	EXAMPLES OF HISTORIC CONTAMINATION SOURCES PROXIMAL TO U.S.S. LEAD 1949	FIGURE B

INTERNAL DRAFT - For Discussio Only

INDIANA HARBOR CANAL

GRAND CALUMET

U.S.S. LEAD CANAL

CANAL

GOLDSCHMIDT DETINNING CO.

INTERNATIONAL LEAD REFINING CO.

REFINERY

BAG HOUSE & STACK

SMELTER

POWERPLANT

office

KENNEDY AVE

LEGEND

- RAILROAD TRACKS
- U.S.S. LEAD PROPERTY BOUNDARY
- WATER BODY
- EXHAUST STACKS
- EXHAUST STACKS

INTERNATIONAL LEAD REFINING CO & GOLDSCHMIDT DETINNING CO.

1915

SOURCE DATA:
1915 SANBORN MAP

NORTH

0' 300 600'

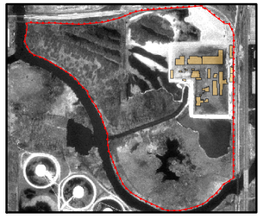
SCALE
1" = 300'

DATE: 7/21/2003 DRAWN BY: CSM CHECKED BY: SHEET OF	ENVIRONMENTAL	Geochemical Solutions Environmental Sampling, Remediation & Compliance	U.S.S. LEAD REFINERY INC. 5300 KENNEDY AVENUE EAST CHICAGO, INDIANA	EXAMPLES OF HISTORIC CONTAMINATION SOURCES PROXIMAL TO U.S.S. LEAD 1915	FIGURE C

INTERNAL DRAFT - For Discussion Only

Figure 3-1

On-Site Sample Locations East Chicago Lake County, Indiana



151st St

TL-23

TL-20

TL-17

TL-19

TL-16

TL-11

TL-7

TL-9

Kennedy Ave

N

W E

S

Note:
Aerial Date 19980412

On-Site Sample Locations
Property Boundary
Facilities

75 37.5 0 75 Meters

200 100 0 200 Feet

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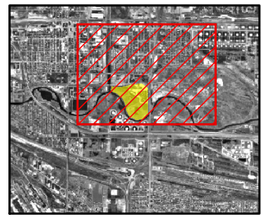
Figure 3-2
Off-Site Sample Locations
East Chicago
Lake County, Indiana



N
W E
S

Note:
Aerial Date 19980412

Off-Site Sample Locations
- Chemical Data
- No Chemical Data

150 75 0 150 Meters

500 250 0 500 Feet

USS Lead Site
- Former Main Stack
- Former Dust Piles
- Former Slag Pile
- Property Boundary
- Former Blast Furnace
- CAMU

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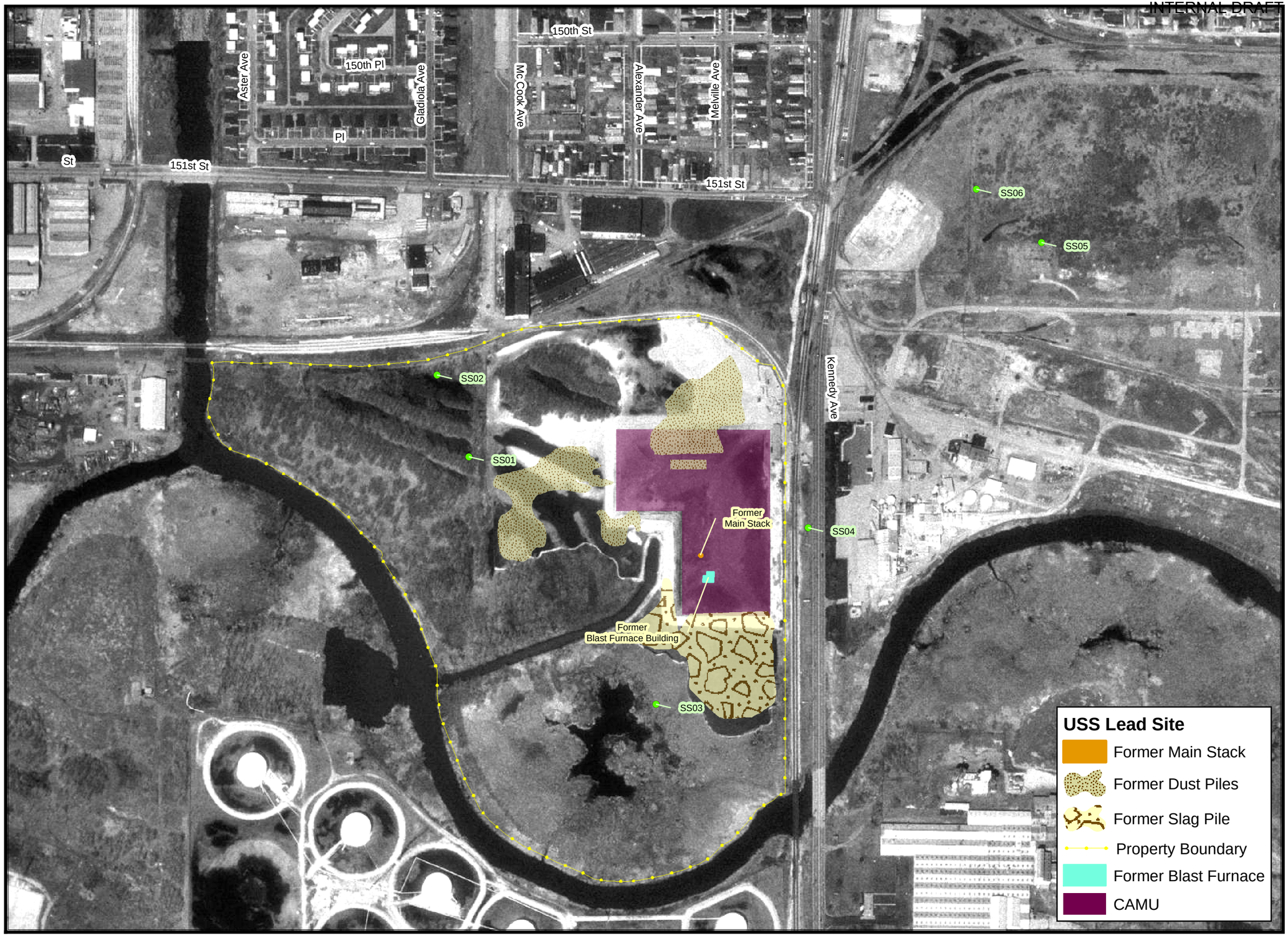
INTERNAL DRAFT - For Discussion Only

Figure 3-3
Off-Site
Sample Locations
Collected 08/15/202
East Chicago
Lake County, Indiana



N
W E
S

Note:
Aerial Date 19980412

Off-Site Sample Locations
● Collected 08/15/2002

75 37.5 0 75 Meters
250 125 0 250 Feet

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TABLES

Appendix A

TechLaw Trip Report for MRFI Field Activities

FIELD OVERSIGHT AND SPLIT SAMPLING REPORT

USS LEAD REFINERY, INC.
EAST CHICAGO, INDIANA
EPA ID NO. IND047030226

Background Information

USS Lead is located at 5300 Kennedy Avenue in East Chicago, Lake County, Indiana. The USS Lead facility previously conducted a secondary lead smelting operation which reclaimed lead from automotive batteries. Industrial activities at the site were discontinued, and the previous manufacturing area has been incorporated into the Corrective Action Management Unit (CAMU). Activities conducted as part of the Interim Stabilization Measures (ISM) include the demolition of the manufacturing buildings at the site, the excavation of lead slag and lead contaminated sediments from the wetlands located south of the manufacturing area, and the excavation of lead contaminated soil and sediments from other portions of the site including the tank area and outfall canal.

Introduction

The personnel present for this field sampling event included:

Ms. Amie Motsinger - TechLaw
Ms. Wendy Trimble - Geochemical Solutions, Inc.
Mr. Norm Johnson - Representative for USS Lead
Mr. Scott ? - Representative for USS Lead

Attachment A of this report contains a photograph log documenting field activities. Attachment B contains photocopies of the field logbooks for the field activities described in this report. The sampling techniques which were described previously are not described again in this Attachment.

This report does not provide detail on the companion sampling that was conducted in off-site areas by a U.S. EPA lead field team. U.S. EPA personnel conducted off-site field screening and surface soil sampling in the vicinity of the USS Lead site from July 23 to August 21, 2003. Containerized soil samples collected by U.S. EPA during this off-site sampling event were provided to TechLaw for analysis by the same methods and laboratories as described in this Report.

Field Oversight Activities

On July 8, 2003, at 0745 Ms. Amie Motsinger arrived on-site and was met by Ms. Wendy Trimble of Geochemical Solutions, Inc. Ms. Trimble informed TechLaw that surface water and fill samples would first be collected. Ms. Trimble also indicated that another field team (consisting of Jeff Woelfer and Dave Kwasiborski) would be collecting groundwater samples at

the same time. Per U.S. EPA direction, TechLaw provided field oversight of the soil, fill and surface water sampling.

The field team walked over the CAMU to the decontamination station that was set up between the USS Lead Canal and the wetlands area. The vegetation on the CAMU appeared to have been taking well; a few small erosion channels were noted. Facility representatives indicated that this was likely due to recent torrential rain storms. When the field team reached the decontamination station, a brief health and safety meeting was held. All equipment was then decontaminated with an alconox solution and double rinsed.

At 0850 a fill sample was collected from the southern portion of the CAMU at sample location 4. The sample was collected from the zero- to six- inch interval for metals analysis. All samples were collected using a stainless steel spoon and bowl. The sample was homogenized and an eight-ounce jar was filled. The hole was filled in after sample collection. The field team indicated that all samples will be sent to Severn Trent Laboratories.

At 0855 a fill sample was collected from the northern portion of the CAMU at sample location 3. The sample was collected from the zero- to six- inch interval for metals analysis. A duplicate fill sample was also collected at this location. It was noted that the vegetation on the south slope of the CAMU is more sparse than in other areas.

At 0925 the pH meter was calibrated. The field team then collected a surface water sample at a pond on the northern portion of the site at sample location 1. Sample location 1 was located alongside the southeastern bank of the pond. The sample was collected using a beaker on a stick. A duplicate surface water sample was also collected at this location. The field team indicated that all water samples would be preserved with nitric acid at once later in the day.

At 0945 a soil/sediment sample was collected at the same location (sample location 1) using a hand auger. The sample was collected underneath the water along the bank. The field team indicated that this sample was to be submitted for the following analyses: metals (with lower method detection levels), Cation Exchange Capacity (CEC), and paste pH.

At 1014 a surface water sample was collected at sample location 2 in a pond further south from sample location 1. The surface water sample was collected using a beaker on a stick to be submitted for Appendix IX metals analysis. A soil/sediment sample was also collected from this location. The soil/sediment sample was collected using a hand auger from a location along the bank beneath the water.

At 1050 the field team collected a surface water sample from the eastern portion of the USS Lead canal at sample location 13. The sample was collected using a beaker on a stick from standing on the southern bank of the canal. A rowboat was used in order to collect the soil/sediment sample from this same location. The field team collected the sample from the zero- to six- inch interval using a hand auger while on the boat. The sample required three volumes from the auger. Since conditions were becoming windy with the boat on the water, it was difficult to

collect the sediment sample in the exact same location, but it was within the same general area.

At 1144 a soil/sediment sample was collected at sample location 12, which was located further west in the USS Lead canal. This sample was collected from the zero- to six-inch interval using a hand auger. The sample container (TerraCore) was filled first for VOC analysis prior to homogenization. Then, the remaining sample containers were filled. No surface water sample was collected at this location.

Conductivity, pH and temperature readings were collected at all surface water sample locations. Sample location 2 showed the highest parameter readings. All surface water samples were then preserved with nitric acid. The sampling equipment was decontaminated between every sample location.

At 1444 a surface water sample was collected at sample location 6. Sample location 6 was located in the eastern portion of the former slag pile location. A boat was used to collect the sample from this location using a beaker on a stick. A sediment sample was also collected at this location using a hand auger. Conductivity, pH and temperature readings were also collected.

At 1500 a soil/sediment sample was collected at sample location 5. Sample location 5 was located to the northwest of sample location 6, also within the former slag pile location. A boat and hand auger were used to collect this sample. At sample location 5, two samples were collected: one at the zero- to six-inch interval and another at the six-inch to two-foot interval.

The pH reading in the pond in the area of the former slag pile was 9.4. However, the field team noted that they did not know if this reading was accurate, as the pH meter was running out of batteries.

It should be noted that it had been raining in the field during sample collection activities. Shortly after sample collection at sample location 5, the field team noted lightning in the sky. Based upon health and safety concerns of using the boat under these weather conditions, it was determined that the last sample (sample location 10) would not be collected that day. The field team indicated that an equipment rinseate blank would be collected and field activities for the day would be complete.

At 1600, TechLaw left the site for the day.

Sampling Activities

On July 9, 2003, Ms. Amie Motsinger arrived on site at 0700. TechLaw met the field team and prepared the equipment for the day. The personnel present were the same as the previous day. The USS Lead field team (USS Lead) consisted of Ms. Trimble, Mr. Johnson and Mr. Scott ? Ms. Trimble indicated that the wetlands would first be sampled, followed by Area 2.

Sampling began at 0755 at sample location 10. USS Lead collected a surface water sample, a

surface (0-6" below ground surface [bgs]) soil/sediment sample and subsurface (6"- 2' bgs) soil/sediment sample at this location. TechLaw collected a split of the surface soil/sediment sample (TL-10) at 0805. For all split samples collected by TechLaw, three 8-ounce glass jars were filled for submittal to the three separate laboratories. The samples collected at this location were collected by using a hand auger while on the boat. As only two people could be on the boat and due to health and safety concerns, two USS Lead representatives collected the samples, while TechLaw observed from the shoreline. In order to obtain the amount of volume needed, a composite sample was collected from three locations directly adjacent to each other.

At 0920, the field teams arrived at sample location 11. Sample location 11 was located approximately 100 feet south southeast of MW-6. The global positioning system (GPS) reading taken by USS Lead at this location was N 41 36.904 and W 87 28.024. USS Lead collected a surface and subsurface sample at this location. TechLaw collected a split of the surface sample (TL-11) at 0930.

At 1130, the field teams arrived at sample location 9. Sample location 9 was very difficult to find due to its location in thick brush in the wetlands. The GPS reading taken by USS Lead at this location was N 41 36.799 and W 87 27.880. USS Lead collected a surface and subsurface sample at this location. USS Lead also collected a duplicate at sample location 9. TechLaw collected a split of the surface sample (TL-9) at 1135. When USS Lead was collecting their subsurface sample, very heavy petroleum odors were noted, and the soils were very saturated. The odors were noted when USS Lead was collecting the soils within the 2nd and 3rd augers (12-18" and 18-24" bgs, respectively). Based upon the conditions noted during sample collection, TechLaw also collected a split of this subsurface sample (TL-9SS) at 1155. However, only one 8-ounce jar was filled for sample analysis.

At 1255, the field team arrived at sample location 7. Sample location 7 was located approximately 75 feet from the pond. The GPS reading taken by USS Lead at this location was N 41 36.881 and W 87 27.757. USS Lead collected a surface and subsurface soil sample at this location. TechLaw collected a split of the surface soil sample (TL-7) at 1300. TechLaw also collected a duplicate (TL-28) at this location. TL-28 was a duplicate of TL-7. The sample collection time assigned to TL-28 was 0800. Water was encountered directly below the vegetation cover at this location.

At 1318, the field team arrived at sample location 8. Sample location 8 was located approximately 200 feet south southeast of sample location 7. USS Lead collected a surface and subsurface sample at this location. TechLaw collected a split of the surface soil sample (TL-8) at 1325.

In summary, at the five wetlands locations to the south of the USS Lead Canal (Sample locations 7, 8, 9, 10 and 11), USS Lead collected both a surface (0-6" bgs) and subsurface (6"-2' bgs) soil sample. In addition, USS Lead collected a surface water sample at sample location 10. TechLaw collected a split surface soil sample at each location, in addition to a split subsurface soil sample at sample location 9. This concluded the wetlands sampling.

The field team then moved all sampling equipment and the decontamination station over to Area 2, the remnant dunes and swale area located to the west of the fence line that runs north-south between the canal and the northern site boundary.

At 1450, the field team arrived at sample location 21. USS Lead collected a surface (0-6" bgs) soil sample at this location. TechLaw collected a split of this surface soil sample (TL-21) at 1450.

At 1505, the field team arrived at sample location 16. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-16) at 1505. TL-27 was also collected at this location. TL-27 was a duplicate of TL-16. The sample time assigned to TL-27 was 1800.

The field team then proceeded to sample location 15. Sample location 15 was located approximately 64 feet south of sample location 16. USS Lead collected a surface and subsurface (6"-2' bgs) soil sample at this location. This was the only location in Area 2 at which USS Lead collected a subsurface soil sample. TechLaw collected a split of the surface soil sample (TL-15) at 1520.

The field team then proceeded to sample location 14. Sample location 14 was located approximately 134 feet south of sample location 15. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-14) at 1535.

Sample location 17 was the next location sampled. Sample location 17 was located approximately 68 feet west of the fence and 280 feet north of location 16. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-17) at 1600. USS Lead also collected a duplicate at this location.

The field team then proceeded to sample location 18. Sample location 18 was located approximately 150 feet north of sample location 17 and 50 feet west of the fence. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-18) at 1630.

Sample location 19 was the next to be sampled. Sample location 19 was located approximately 215 feet west of the fence and 235 feet north of location 16. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-19) at 1650.

At 1715, USS Lead collected a rinseate blank. Distilled water was poured into a decontaminated bowl and stirred with a decontaminated spoon. A sample was then collected and submitted for laboratory analysis.

At 1735, the field team then proceeded to sample location 22. USS Lead collected a surface soil sample at this location. Based on field discretion, and with approval from U.S. EPA, TechLaw did not collect a split sample at this location.

The USS Lead team proceeded to sample location 24 to collect a surface soil sample. As TechLaw was directed by U.S. EPA to not collect a split sample at this location, TechLaw did not accompany the USS Lead field team. Instead, as directed by U.S. EPA, TechLaw walked through the northwest corner of the site to observe site conditions based upon an historical aerial photograph provided by the U.S. EPA Technical Advisor (TA). The area was slightly less vegetated, but no areas of concern were noted. TechLaw then met up with Ms. Trimble, as she requested to be present for any sample collection.

TechLaw collected an opportunistic surface soil sample (TL-26) in this area at 1810. The sample was collected using a decontaminated stainless steel bowl and spoon. The sample was collected at this location in case any areas of concern were later noted, however its analysis was not deemed necessary.

The field team then proceeded to sample location 23. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-23) at 1825.

Sample location 20 was the final location to be sampled. USS Lead collected a surface soil sample at this location. TechLaw collected a split of this surface soil sample (TL-20) at 1850.

This concluded the sampling activities for the day and all soil sampling activities to be conducted under the MRFI. In summary, USS Lead collected surface soil samples at all Area 2 sample locations (Sample locations 14-24). In addition, USS Lead collected one subsurface soil sample at sample location 15. TechLaw collected a split surface soil sample at all Area 2 locations, with the exception of sample locations 22 and 24. In addition, TechLaw collected one opportunistic sample (TL-26) at the very northwest comer of the site.

TechLaw left the site at 1915.

All samples were then labeled, tagged, placed on ice in coolers and chilled to a temperature less than 4 degrees centigrade. The samples were kept in a secure environment (i.e., under direct control of the sampling team) to preserve sample integrity prior to shipment to the laboratories.

The samples were sent to three laboratories with instructions to hold the samples until further directed by TechLaw. The purpose was to first observe the results obtained by USS Lead and only analyze those split samples with significant concentrations of lead or other metals.

A number of off-site samples were collected by U.S. EPA personnel during a sampling event separate from the abovementioned TechLaw field activities. Those samples were collected and maintained under the custody of U.S. EPA personnel. The chains of custody were initiated by the U.S. EPA sampling team. Custody was then transferred to the U.S. EPA Region 5 Central Regional Laboratory (CRL) in Chicago, Illinois at the conclusion of the field event. TechLaw later retrieved the samples from CRL and retained custody. The samples were then sent to two of the laboratories used by TechLaw for the abovementioned sampling event, AATS and LEGS.

Analysis

Some of the containerized samples collected under this sampling event were subjected to the suite of analytical methods that were established for this project. The samples were initially held by the laboratories pending receipt of split sample analytical results from the USS Lead contract laboratory. Samples determined to represent both wetland and upland areas and to contain significant lead concentrations based on the USS Lead split sample analytical results were analyzed to determine additional information about the characteristics of the lead detected at the USS Lead site. The total number of on-site samples analyzed by sieving, ICP/MS and EMPA analysis was eight samples.

The following sample analysis methodology was followed:

- One of the three sample jars from each location was sent to American Analytical and Technical Services, Inc. in Baton Rouge, Louisiana.
- The sample was sieved through a 100 mesh (150 micron) screen.
- Fine fraction and residual fraction masses were carefully recorded.
- Fine fraction, residual fraction and some bulk samples were analyzed by inductively coupled plasma/mass spectrometry (ICP/MS).
- The semiquantitative analysis included NIST standard 981 to evaluate the lead isotope abundances in the samples (i.e., comparable to an isotope ratio report).

- One of the three jars was submitted for electron microprobe analysis (EMPA) to Dr. John Drexler s laboratory at the University of Colorado.

- One of the three sample jars was shipped to the National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio. NRMRL was prepared to conduct x-ray diffraction (XRD) analysis on soil samples to identify lead species. It was recognized that the XRD techniques requested from NRMRL may not identify individual lead-mineral phases that are present in the sample at abundances less than 1-2%. It was also recognized that the NRMRL XRD analysis would have only been of a survey nature and the results would not have been quantitative. The off-site samples collected by U.S. EPA were not sent to this laboratory.

Analytical Results/Discussion

APPENDIX A

PHOTOGRAPH LOG

Photograph No.: R1P1 Time: 0845
Date: 7/8/03 Direction: West

Description: View of sample location 4 on the southern portion of the CAMU.

Photograph No.: R1P2 Time: 0855
Date: 7/8/03 Direction: West

Description: View of sample location 3 on the northern portion of the CAMU.

Photograph No.: R1P3 Time: 0925
Date: 7/8/03 Direction: West Northwest

Description: View of sample location 1 on the southeastern corner of the northern pond.

Photograph No.: R1P4 Time: 1014
Date: 7/8/03 Direction: West

Description: View of sample location 2 on the pond to the south of sample location 1.

Photograph No.: R1P5 Time: 1050
Date: 7/8/03 Direction: Northwest

Description: View of sample location 13 in the eastern portion of the USS Lead Canal.

Photograph No.: R1P6 Time: 1144
Date: 7/8/03 Direction: North Northwest

Description: View of sample location 12 in the western portion of the USS Lead Canal.

Photograph No.: R1P7 Time: 1415
Date: 7/8/03 Direction: East Northeast

Description: View of sample location 6 in the eastern portion of the former slag pile location.

Photograph No.: R1P8 Time: 1500
Date: 7/8/03 Direction: East Southeast

Description: View of sample location 5 in the western portion of the former slag pile location.

Photograph No.: R1P9 Time: 0809
Date: 7/9/03 Direction: South

Description: View of sample location 10.

Photograph No.: R1P10 Time: 0949
Date: 7/9/03 Direction: South

Description: View of sample location 11.

Photograph No.: R1P11 Time: 1140
Date: 7/9/03 Direction: Southeast

Description: View of sample location 9. Note the two large tanks in the background. They are the two tanks furthest east on the property across the river.

Photograph No.: R1P12 Time: 1309
Date: 7/9/03 Direction: West

Description: View of sample location 7. Note the white tanks in the background. They are the third and fourth tanks from the east on the property across the river.

Photograph No.: R1P13 Time: 1450
Date: 7/9/03 Direction: West

Description: View of sample location 21.

Photograph No.: R1P14 Time: East
Date: 7/9/03 Direction:

Description: View of sample location 16. A duplicate (TL-27) was also collected at this location.

Photograph No.: R1P15 Time: 1520
Date: 7/9/03 Direction: East

Description: View of sample location 15.

Photograph No.: R1P16
Date: 7/9/03

Time: 1530
Direction: North northwest

Description: View of sample location 14.

Photograph No.: R1P17 Time: 1815
Date: 7/9/03 Direction: East

Description: View of sample location TL-26, where the opportunistic sample was collected.

Photograph No.: R1P18 Time: 1816
Date: 7/9/03 Direction: East

Description: Distant view of sample location TL-26.

ATTACHMENT B

FIELD LOGBOOK

Appendix B

Lead Speciation Lab Report

USS Lead
Chicago, Illinois

LEAD SPECIATION LAB REPORT

October 24, 2003

Prepared for:

TechLaw Inc.

Prepared by:
Laboratory for Environmental and Geological Studies (LEGS)
University of Colorado
Benson Earth Science
2200 Colorado Ave.
Boulder, CO 80309

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Appendix A. Chain-of-Custody
CD ROM All raw data files, backscatter photomicrographs, and spectra.

Definitions:

$PbCO_3$ = Cerussite
PbMO = Lead metal Oxide, metals are typically As, Sn and/or Sb
$PbMSO_4$ = Lead metal Sulfate, metals are typically As, Sn and/or Sb
$PbSO_4$ = Anglesite
PbS = Galena
PbO = Lead Oxide
BSPM = Backscatter photomicrograph of BE! (backscatter electron image)
EPMA = Electron microprobe analysis

Introduction

TechLaw Inc. requested lead speciation be conducted on a set of 31. Samples were collected by TechLaw and delivered to LEGS at the University of Colorado under Chain-of-custody (Appendix I). Samples were air-dried and sieved to <2mm prior to preparation for EMPA speciation. No review nor interpretation of the data was requested.

Speciation Methodology

The Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado, Department of Geological Sciences contains the following equipment was used for this project:

> A JOEL 8600 electron microprobe, with four wavelength dispersive detectors (TAP, LIF, PET, LdB, LdC and Ld1 crystals) and an energy dispersive detector. The system includes backscatter and secondary detectors for imaging and can produce both x-ray spectra and photomicrographs in TIF format. Certified mineral standards for all elements of concern are available for EMPA standardization. SOP for metal speciation is available at our website:
>
> http://www.colorado.edulGeolSci/legs/speciation.html

Representative backscatter photomicrographs (BSPM) illustrating sample characteristics were acquired (project name, date and sample/photo number are recorded on photo) and EDS spectra (with corresponding photo number) acquired and it is recommended the client review these images. Data from EMPA will be summarized using two methods as illustrated below.

The first method is the determination **of FREQUENCY OF OCCURRENCE. This is** calculated by summing the longest dimension of all the lead/arsenic bearing phases observed and then dividing each phase by the total.

Equation 1.0 will serve as an example to the calculation for a lead-bearing compound.

F_{Pb} - Frequency of occurrence of lead in a single phase.

PLD - An individual particles longest dimension

$$F_{Pb} \text{ in phase-1} = \frac{\sum (PLD)_{\text{phase-1}}}{\sum (PLD)_{\text{phase-1}} + \sum (PLD)_{\text{phase-2}} + \sum (PLD)_{\text{phase-n}}}$$

$$\%F_{Pb} \text{ in phase-1} = F_{Pb} \text{ in phase-1} * 100$$

This data thus illustrates which lead-bearing phase(s) are the most commonly observed in the sample or relative volume percent.

The second calculation used in this report is the determination of **RELATIVE MASS of a**

lead/arsenic bearing phase. These data are calculated (using lead as an example) by substituting the PLD term in the equation above with the value of Mpb. This term is calculated as defined below.

M_{Pb} - Mass of lead in a phase

SG - Specific Gravity of a phase

ppm_{Pb} - Concentration in ppm of lead in phase

$$M_{Pb} = F_{Pb} * SG * ppm_{Pb}$$

The advantage in reviewing the RELATIVE MASS determination is that it gives one information as to which metal-bearing phase(s) in a sample are likely to control the total bulk concentration for the metal. As an example, PHASE-I may by relative volume comprise 98% of the sample, however it has a low specific gravity and contains only 1000 ppm lead, while PHASE-2 comprises 2% of the sample, has a high specific gravity and contains 850000 ppm of lead. In this example it is PHASE-2 that is the dominant source of lead to the sample.

Sample Preparation

1) Logging the samples of which polished mounts will be prepared

2) Inspection of all plastic cups, making sure each is clean and dry

3) Labeling each “mold” with its corresponding sample number.

4) All samples will be split to produce a homogeneous 1-4 gram sample.

5) Mixing epoxy resin and hardener according to manufacturer's directions.

6) Pour 1 gram of sample into mold. Double checking to make sure sample numbers on mold and sample match. Pouring epoxy into mold to just cover sample grains.

7) Using a new wood stirring stick with each sample, carefully blend epoxy and grains so as to coat all grains with epoxy.

8) Setting molds to cure at ROOM TEMPERATURE in a clean restricted area. Adding labels with sample numbers and covering with more epoxy resin. Leaving to cure completely at room temperature.

9) One at a time, removing each sample from its mold and grinding flat the back side of the mount.

10) Using 600 grit wet abrasive paper stretched across a grinding wheel for removing the bottom layer and exposing as many mineral grains as possible. Follow with 1000 grit paper.

11) Start polishing with l5u oil based diamond paste on a polishing paper fixed to a lap. Using paper instead of cloth minimizes relief.

12) Next use 6u diamond polish on a similar lap.

13) Finally polish the sample with 1u oil based diamond past on polishing paper. Followed by .05u alumina in water suspension. The quality should be checked after each step. Typical polishing times are 30 minutes for l5u, 20 minutes for 6u, 15 minutes for 1u and 10 minutes for .05u.

NOTE: use low speed on the polishing laps to avoid "plucking" of sample grains.

14) Samples should be completely cleaned in an ultrasonic cleaner with isopropyl alcohol or similar solvent to remove oil and finger prints.

15) To insure that no particles of lead are being cross contaminated with sample preparation procedures, a blank epoxy only) mold will be made every 50th sample following all of the above procedures. This mold will then be speciated along with the other samples.

16) Each sample be carbon coated. Once coated the samples should be stored in a clean, dry environment with the carbon surface protected from scratches or handling.

POINT COUNTING

Counts are made by traversing each sample from left-to-right and top-to-bottom. The amount of vertical movement for each traverse would depend on magnification and CRT (cathode-ray tube) size. This movement should be minimized so that NO portion of the sample is missed when the end of a traverse is reached. Two magnification settings should be used. One ranging from 40-100X and a second from 300-600X. The last setting will allow one to find the smallest identifiable (1-2 micron) phases.

The portion of the sample examined in the second pass, under the higher magnification, will depend on the time available, the number of lead-bearing particles, and the complexity of metal mineralogy. A maximum of 8 hours will be spent per sample.

SPECIATION

The soil samples from the USS Lead site (Table 1) were speciated for lead, using electron microprobe (EMPA) techniques. Methodologies used for sample preparation, data collection, and data synthesis are described above. Data are summarized in Figures 1 -2 and individual sample results are provided in Table 2 and 3.

Table 1. USS Lead site sample set.

Client Sample Number	Lab ID	Lead Concentration
On Site		mg/kg
MRFI-SS-7A	TL-7	na
MRFI-SS-9A	TL-9	na
MRFI-SS-11A	TL-11	na
MRFI-SS-16	TL-16	na
MRFI-SS-17	TL-17	na
MRFI-SS-I9**	TL-19	na
MRFI-SS-20	TL-20	na
MRFI-SS-23	TL-23	na
Off Site		
S-03	S-03	na
S-04	S-04	na
S-06	S-06	na
S-07	S-07	na
S-08	S-08	na
S-09	S-09	na
S-11	S-11	na
S-12	S-12	na
S-14	S-14	na
S-15	S-15	na
S-16x49	S-16	na
S-17x50	S-17	na
S-21 x76	S-21	na
S-22 x73	S-22	na
S-23 x79	S-23	na
S-26	S-26	na
S-27	S-27	na
S-28	S-28	na
S-29	S-29	na
D-03**	D-03	na
S-20 x 66	S-20	na

** Designated for duplicate analyses.

Table 2. Speciation summary for on-site samples.

	Phase	F%	%RM-Pb	E-95%**
TL-11	Anglesite	0.19%	5.30%	0.8%
	FeOOH	94.31%	65.24%	4.2%
	MnOOH	3.89%	12.81%	3.5%
	PbMO	0.53%	7.68%	1.3%
	PbO	0.13%	7.24%	0.6%
	SbMO	0.36%	0.91%	1.1%
	SnMO	0.59%	0.83%	1.4%
TL-23	Brass	4.72%	0.05%	4.1%
	FeOOH	43.12%	11.69%	9.7%
	MnOOH	0.82%	1.06%	1.8%
	PbMO	9.45%	53.73%	5.7%
	PbTiO2	1.44%	9.82%	2.3%
	SbMO	3.29%	3.26%	3.5%
	SnMO	37.17%	20.40%	9.4%
TL-20	Brass	1.52%	0.01%	2.2%
	FeOOH	49.43%	10.19%	9.0%
	Galena	0.25%	3.17%	0.9%
	MnOOH	20.71%	20.31%	7.3%
	PbMO	13.34%	57.68%	6.1%
	PbSiO2	1.02%	2.46%	1.8%
	SbMO	2.03%	1.53%	2.5%
	SnMO	9.15%	3.82%	5.2%
	Fe Sulfate	2.54%	0.83%	2.8%
TL-16	Anglesite	0.36%	6.80%	1.6%
	Brass	10.71%	0.20%	8.1%
	FeOOH	72.50%	34.34%	11.7%
	Galena	0.36%	10.25%	1.6%
	MnOOH	1.79%	4.02%	3.5%
	PbMO	3.57%	35.49%	4.9%
	SbMO	0.71%	1.24%	2.2%
	SnMO	0.71%	0.68%	2.2%
	Fe Sulfate	9.29%	6.98%	7.6%
TL-7	Anglesite	29.29%	91.86%	5.2%
	AsS2	0.51%	0.00%	0.8%
	Bante	0.11%	0.00%	0.4%
	FeOOH	11.88%	0.93%	3.7%
	Fe Sulfate	58.22%	7.21%	5.6%

Table 2. Speciation summary for on-site samples.

	Phase	F%	%RM-Pb	E-95%**
TL-I7	Pb-Al-Si02	0.84%	1.72%	1.6%
	Anglesite	0.28%	2.94%	0.9%
	Brass	2.95%	0.03%	3.0%
	FeOOH	47.47%	12.38%	8.8%
	MnOOH	19.24%	23.87%	6.9%
	PbAsO	0.14%	0.58%	0.7%
	PbMO	8.57%	46.88%	4.9%
	SbMO	2.81%	2.68%	2.9%
	SnMO	13.90%	7.34%	6.1%
	Fe Sulfate	3.79%	1.57%	3.3%
TL-9	Anglesite	4.82%	65.04%	3.1%
	Barite	1.00%	0.10%	1.5%
	Brass	0.19%	0.00%	0.6%
	FeOOH	78.93%	26.50%	6.0%
	PbMO	0.05%	0.34%	0.3%
	SnMO	0.19%	0.13%	0.6%
	Fe Sulfate	14.82%	7.90%	5.2%
TL-19	Brass	0.41%	0.00%	1.3%
	FeOOH	35.54%	5.44%	9.3%
	MnOOH	11.78%	8.58%	6.3%
	PbMO	22.31%	71.70%	8.1%
	PbSiO2	2.89%	5.21%	3.3%
	SbMO	2.69%	1.50%	3.2%
	SnMO	24.38%	7.56%	8.4%
TL-19-Dup	Brass	2.64%	0.02%	3.0%
	FeOOH	29.07%	6.02%	8.4%
	MnOOH	17.48%	17.21%	7.1%
	PbCrO4	1.63%	6.18%	2.4%
	PbMO	12.20%	52.95%	6.1%
	SbMO	6.30%	4.77%	4.5%
	SnMO	30.69%	12.86%	8.6%

**E-95% = Counting error at 95% confidence limit on F% estimates, based on Mosimann, 1965. The reported errors serve only to remind the reader that when total particle counts are low , the observed frequency is in greater doubt.

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
SO-4	Pb-Al-Si02	4.83%	9.82%	3.8%
	Anglesite	0.94%	9.79%	1.7%
	FeOOH	62.42%	16.19%	8.5%
	MnOOH	7.38%	9.11%	4.6%
	Paint	2.68%	1.75%	2.8%
	PbFeOOH	1.21%	1.47%	1.9%
	PbMO	5.77%	31.40%	4.1%
	PbO	0.27%	5.74%	0.9%
	PbTiO2	0.27%	1.75%	0.9%
	Phosphate	3.22%	7.79%	3.1%
	SbMO	0.27%	0.25%	0.9%
	SnMO	4.43%	2.33%	3.6%
	Fe Sulfate	6.31%	2.60%	4.3%
SO-3	Anglesite	0.41%	3.55%	1.1%
	AsMO	0.10%	0.61%	0.6%
	Cerussite	0.31%	3.17%	1.0%
	FeOOH	59.57%	12.86%	8.8%
	MnOOH	3.58%	3.68%	3.3%
	PbFeOOH	2.05%	2.08%	2.5%
	PbMO	6.35%	28.75%	4.4%
	PbTiO2	0.10%	0.56%	0.6%
	Phosphate	20.88%	42.06%	7.3%
	SnMO	4.20%	1.83%	3.6%
	Fe Sulfate	2.46%	0.84%	2.8%
S-12	FeOOH	84.62%	42.91%	7.0%
	MnOOH	1.82%	4.39%	2.6%
	Paint	4.00%	5.11%	3.8%
	PbBr	0.18%	3.69%	0.8%
	PbMO	3.28%	34.84%	3.5%
	Phosphate	1.18%	5.59%	2.1%
	SbMO	0.55%	1.01%	1.4%
	SnMO	1.82%	1.87%	2.6%
	ZnMO	2.55%	0.58%	3.1%
S-23	FeOOH	30.35%	5.92%	7.1%
	MnOOH	57.28%	53.15%	7.6%
	PbMO	9.67%	39.56%	4.5%
	SbMO	0.98%	0.70%	1.5%
	SnMO	1.71%	0.68%	2.0%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
S-14	Anglesite	1.03%	12.78%	1.8%
	Barite	1.18%	0.11%	1.9%
	FeOOH	69.71%	21.53%	8.1%
	MnOOH	5.29%	7.78%	3.9%
	PbMO	3.24%	20.96%	3.1%
	Phosphate	11.18%	32.20%	5.5%
	SbMO	0.44%	0.50%	1.2%
	SnMO	1.91%	1.20%	2.4%
	Fe Sulfate	6.03%	2.96%	4.2%
S-26	Anglesite	0.45%	3.71%	1.2%
	FeOOH	49.61%	10.14%	9.2%
	MnOOH	13.08%	12.72%	6.2%
	PbFeOOH	0.56%	0.54%	1.4%
	PbMO	6.88%	29.49%	4.7%
	Phosphate	20.97%	39.99%	7.5%
	SnMO	7.55%	3.13%	4.9%
	Fe Sulfate	0.90%	0.29%	1.7%
S-17	Pb-Al-Si02	3.25%	4.05%	3.2%
	Cerussite	7.90%	60.07%	4.9%
	FeOOH	71.49%	11.37%	8.2%
	MnOOH	3.18%	2.40%	3.2%
	PbAsO	0.78%	1.96%	1.6%
	PbCrO4	0.64%	1.85%	1.4%
	PbMO	3.60%	12.01%	3.4%
	Phosphate	3.03%	4.50%	3.1%
	SnMO	3.32%	1.07%	3.2%
	Fe Sulfate	2.82%	0.71%	3.0%
S-15	Brass	3.27%	0.07%	3.5%
	FeOOH	83.27%	43.54%	7.3%
	MnOOH	0.85%	2.11%	1.8%
	PbMO	3.27%	35.90%	3.5%
	PbSiO2	0.24%	1.49%	1.0%
	Phosphate	1.94%	9.46%	2.7%
	SbMO	0.85%	1.62%	1.8%
	SnMO	3.15%	3.34%	3.4%
	Fe Sulfate	2.91%	2.42%	3.3%
	ZnMO	0.24%	0.06%	1.0%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
S-29	Pb-Al-Si02	2.46%	7.05%	3.0%
	FeOOH	78.40%	28.62%	8.0%
	MnOOH	4.34%	7.54%	4.0%
	PbMO	6.22%	47.64%	4.7%
	Phosphate	1.41%	4.80%	2.3%
	SnMO	3.99%	2.95%	3.8%
	Fe Sulfate	2.11%	1.22%	2.8%
	ZnMO	1.06%	0.17%	2.0%
S-16	Pb-Al-Si02	20.06%	41.27%	7.7%
	Brass	1.29%	0.01%	2.2%
	Cerussite	0.64%	8.09%	1.5%
	Clay	0.97%	0.09%	1.9%
	FeOOH	49.15%	12.90%	9.7%
	MnOOH	7.01%	8.76%	4.9%
	Paint	7.25%	4.80%	5.0%
	PbAsO	0.08%	0.34%	0.5%
	PbMO	3.14%	17.31%	3.4%
	PbTiO2	0.24%	1.60%	0.9%
	Phosphate	0.24%	0.59%	0.9%
	SnMO	2.66%	1.41%	3.1%
	Fe Sulfate	6.61%	2.75%	4.8%
	ZnMO	0.64%	0.08%	1.5%
S-11	Pb-Al-Si02	0.59%	1.38%	1.5%
	Brass	0.17%	0.00%	0.8%
	Cerussite	0.08%	1.20%	0.6%
	FeOOH	53.65%	16.06%	9.6%
	MnOOH	6.80%	9.69%	4.8%
	Paint	14.95%	11.27%	6.9%
	PbMO	2.60%	16.35%	3.1%
	PbTiO2	0.42%	3.17%	1.2%
	Phosphate	13.01%	36.34%	6.5%
	SbMO	0.25%	0.28%	1.0%
	SnMO	5.54%	3.36%	4.4%
	Fe Sulfate	1.93%	0.92%	2.6%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
S-22	Pb-Al-Si02	0.52%	2.27%	1.4%
	Brass	5.62%	0.12%	4.4%
	FeOOH	83.40%	46.24%	7.1%
	MnOOH	2.22%	5.86%	2.8%
	PbFeOOH	0.13%	0.34%	0.7%
	PbMO	2.61%	30.41%	3.1%
	Phosphate	2.22%	11.49%	2.8%
	SnMO	1.57%	1.76%	2.4%
	Fe Sulfate	1.70%	1.50%	2.5%
S-27	Brass	1.18%	0.02%	1.9%
	FeOOH	73.94%	29.74%	7.8%
	MnOOH	1.95%	3.72%	2.5%
	PbMO	3.47%	29.27%	3.3%
	Phosphate	7.53%	28.25%	4.7%
	SnMO	7.78%	6.34%	4.8%
	Fe Sulfate	4.15%	2.65%	3.6%
S-28	Pb-Al-Si02	7.85%	28.57%	5.1%
	FeOOH	79.73%	37.04%	7.7%
	MnOOH	8.37%	18.50%	5.3%
	PbMO	1.31%	12.75%	2.2%
	SbMO	0.72%	1.22%	1.6%
	SnMO	2.03%	1.91%	2.7%
S-21	Pb-Al-Si02	0.16%	0.73%	0.7%
	Anglesite	0.16%	3.74%	0.7%
	Brass	1.96%	0.05%	2.6%
	FeOOH	92.02%	54.78%	5.0%
	MnOOH	0.55%	1.55%	1.4%
	PbMO	2.82%	35.18%	3.1%
	Phosphate	0.31%	1.74%	1.0%
	SnMO	1.17%	1.41%	2.0%
	Fe Sulfate	0.86%	0.81%	1.7%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
D03-dup	FeOOH	45.77%	7.82%	10.6%
	MnOOH	7.31%	5.94%	5.5%
	PbCrSiO2	5.38%	10.82%	4.8%
	PbFeOOH	4.42%	3.55%	4.4%
	PbMO	9.04%	32.41%	6.1%
	Phosphate	23.46%	37.41%	9.0%
	SbMO	1.92%	1.20%	2.9%
	SnMO	1.54%	0.53%	2.6%
	Fe Sulfate	1.15%	0.31%	2.3%
D0-3	Pb-Al-Si02	0.50%	0.64%	1.3%
	FeOOH	46.82%	7.66%	9.1%
	MnOOH	5.10%	3.97%	4.0%
	PbAsO	0.25%	0.65%	0.9%
	PbCrSiO2	6.69%	12.87%	4.5%
	PbFeOOH	0.25%	0.19%	0.9%
	PbMO	8.11%	27.85%	5.0%
	PbTiO2	0.17%	0.69%	0.7%
	Phosphate	28.85%	44.05%	8.2%
	SbMO	1.42%	0.85%	2.2%
	SnMO	1.25%	0.42%	2.0%
	Fe Sulfate	0.59%	0.15%	1.4%
S-20	Pb-Al-Si02	1.90%	4.65%	2.6%
	Brass	0.54%	0.01%	1.4%
	FeOOH	72.69%	22.67%	8.5%
	MnOOH	2.45%	3.63%	2.9%
	PbCrO4	0.68%	3.89%	1.6%
	PbMO	6.39%	41 .77%	4.7%
	Phosphate	6.25%	18.18%	4.6%
	SnMO	5.16%	3.26%	4.2%
	Fe Sulfate	3.94%	1.95%	3.7%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
S-09	Pb-Al-Si02	1.36%	2.71%	2.0%
	Brass	0.80%	0.01%	1.6%
	FeOOH	56.12%	14.26%	8.7%
	Galena	0.16%	2.46%	0.7%
	MnOOH	3.44%	4.16%	3.2%
	Paint	7.99%	5.12%	4.8%
	PbFeOOH	1.84%	2.20%	2.4%
	PbMO	4.80%	25.58%	3.7%
	PbSiO2	4.72%	14.09%	3.7%
	PbTiO2	0.24%	1.54%	0.9%
	Phosphate	10.31%	24.45%	5.3%
	SnMO	5.20%	2.67%	3.9%
	Fe Sulfate	1.44%	0.58%	2.1%
	ZnMO	1.60%	0.18%	2.2%
S-08	Pb-Al-Si02	8.22%	17.51%	5.3%
	AsS2	0.57%	0.00%	1.5%
	FeOOH	50.32%	13.68%	9.7%
	MnOOH	1.20%	1.56%	2.1%
	Paint	21.97%	15.05%	8.0%
	PbMO	5.10%	29.11%	4.3%
	PbSiO2	2.55%	8.15%	3.1%
	PbTiO2	0.28%	1.94%	1.0%
	Phosphate	3.90%	9.89%	3.8%
	SbMO	0.21%	0.21%	0.9%
	SnMO	3.83%	2.11%	3.7%
	Fe Sulfate	1.84%	0.80%	2.6%
S-07	Pb-Al-Si02	4.50%	12.40%	4.0%
	Cerussite	1.30%	21.85%	2.2%
	FeOOH	78.02%	27.47%	8.0%
	MnOOH	1.00%	1.67%	1.9%
	PbMO	2.20%	16.24%	2.8%
	Phosphate	4.20%	13.78%	3.9%
	SbMO	1.20%	1.54%	2.1%
	SnMO	5.19%	3.70%	4.3%
	Fe Sulfate	2.40%	1.34%	3.0%

Table 3. Speciation summary for off-site samples.

	Phase	F%	%RM-Pb	E-95%**
S-06	FeOOH	48.31%	16.29%	8.8%
	MnOOH	12.05%	19.33%	5.7%
	Paint	8.38%	7.11%	4.9%
	PbMO	5.41%	38.29%	4.0%
	SbMO	3.37%	4.16%	3.2%
	SnMO	18.90%	12.90%	6.9%
	Fe Sulfate	3.58%	1.91%	3.3%

**E-95% Counting error at 95% confidence limit on F% estimates, based on Mosimann, 1965. The reported errors serve only to remind the reader that when total particle counts are low, the observed frequency is in greater doubt.

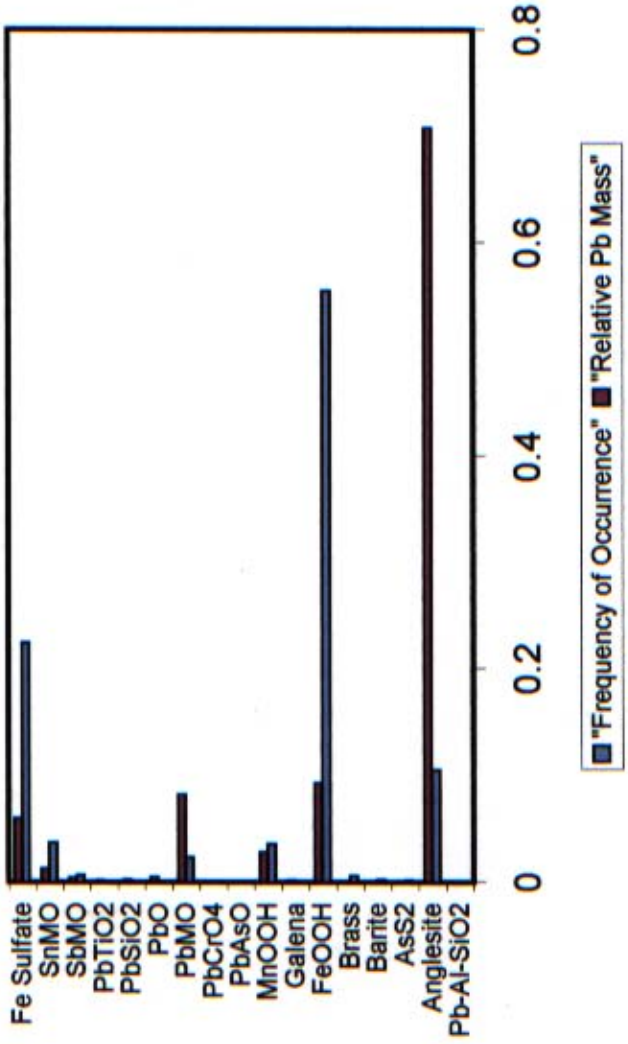

Figure 1. Summary lead speciation

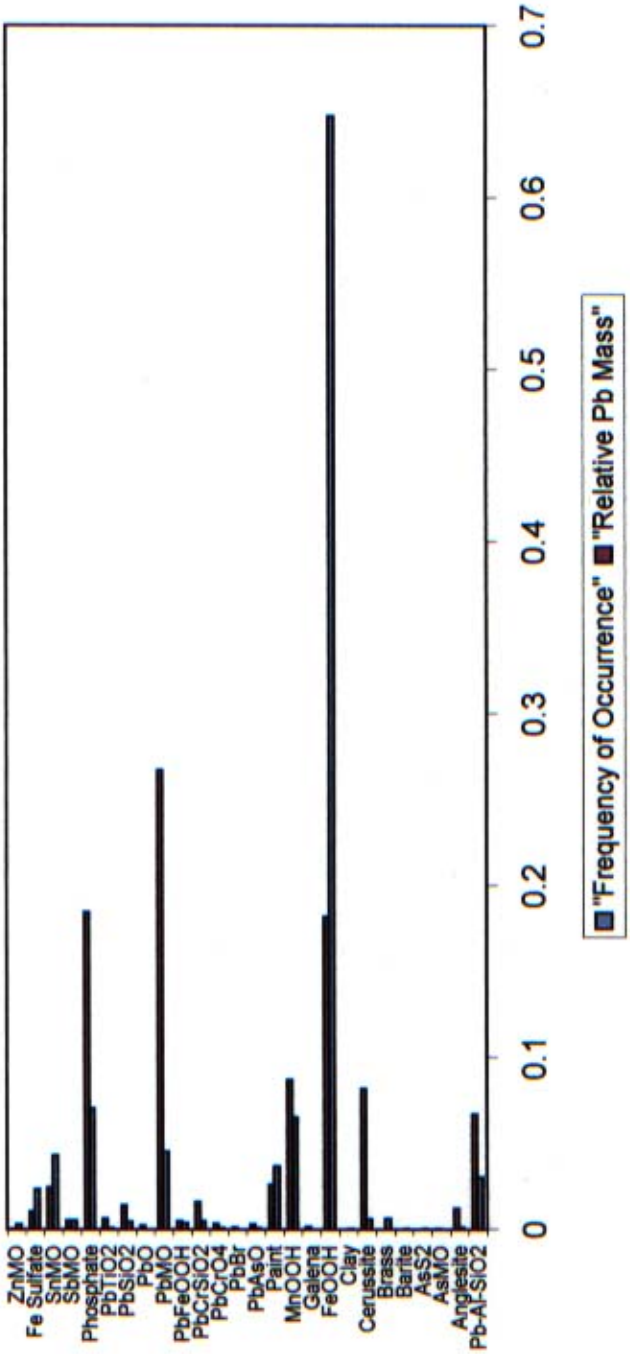

Figure 2. Summary lead speciation.

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Appendix C

El Paso Report Prepared by the LEGS Laboratory

A STUDY ON

THE SOURCE OF ANOMALOUS LEAD and ARSENIC CONCENTRATIONS IN SOILS FROM THE El PASO COMMUNITY--- El PASO, TEXAS.

June 5, 2003

FOR

ENVIRONMENTAL PROTECTION AGENCY

BY

DR. JOHN W. DREXLER
LABORATORY FOR ENVIRONMENTAL AND GEOLOGICAL STUDIES
UNIVERSITY OF COLORADO
BOULDER, CO. 80309

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ABBREVIATIONS

EMPA	Electron Microprobe Analysis
EDS	Energy Dispersive Spectrometer
SOP	Standard Operating Procedure
BSPM	Backscatter photomicrograph

Galena (PbS)

Cerussite ($PbCO_3$)

Anglesite ($PbSO_4$)

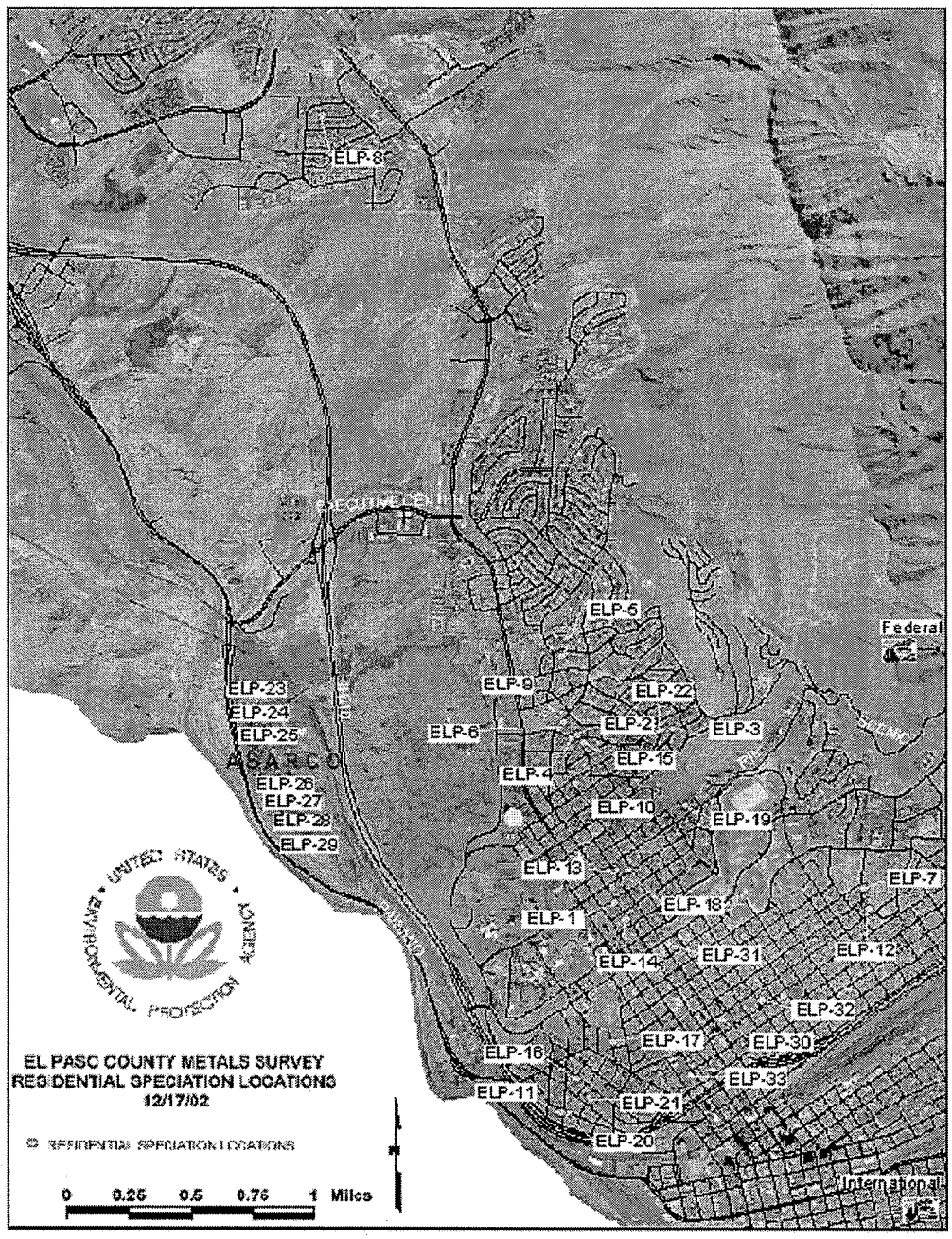
Sulfosalts (enargite- Cu_3AsS_4; tetrahedrite- $Cu_{12}Sb_4S_{13}$; tennantite- $Cu_{12}As_4S_{13}$; bournonite-$PbCuSbS_3$; and jamesonite-$Pb_4FeSb_6S_{14}$)

1.0 INTRODUCTION

The purpose of this study was to characterize the lead and arsenic mineralogy within the El Paso community soils and more specifically the source(s) of the anomalously high (121-1143 mg/kg) lead and (14-192 mg/kg) arsenic concentrations found in the community. Samples were acquired from the ASARCO (1889-present) facility in El Paso, in addition to those collected by WESTON from the surrounding community. Although the ASARCO facility was not the only smelter to operate in the El Paso community, it was the largest and had the greatest longevity. The International Smelter operated from 1888-1894 and the Federal smelter operated from 1901-1904. A site map, with sample locations and selected demographics is provided in Figure 1. Environmental concerns pertaining to plant discharges began in the early 1920's with various private and city disputes concerning damages to crops and health from excessive smoke releases. In the early 1970's more aggressive action by the city of El Paso and the state of Texas was undertaken to control air pollution from the facility. During these investigations it was concluded that the ASARCO smelter emitted approximately 1,000 tons of lead, 500 tons of zinc, 10 tons of cadmium and 1 ton of arsenic to the surrounding area over a three year period (People vs ASARCO, 1971 and Carnow et al., 1973). As a direct result of this litigation ASARCO completed a $90 million dollar renovation to the facility in 1979 to improve emission quality. However, as recently as 1990, data from the State of Texas indicate that 96 tons of lead per year (from the ore and fluid beds) and 29 tons of arsenic per year (from the copper stack) are still being emitted from the facility. These modern, measured releases could only pale in comparison to historic releases during the facilities 100+ years of operation.

7

Fig1


ELP-8
ELP-5
Federal
ELP-23
ELP-24
ELP-25
ELP-9
ELP-22
ELP-6
ELP-2
ELP-3
ELP-16
ASARCO
ELP-4
ELP-26
ELP-27
ELP-28
ELP-29
ELP-10
ELP-19
ELP-13
ELP-7
ELP-18
ELP-1
ELP-14
ELP-31
ELP-12
ELP-32
ELP-17
ELP-30
ELP-16
ELP-33
ELP-11
ELP-21
ELP-20
International
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EL PASC COUNTY METALS SURVEY
RESIDENTIAL SPECIATION LOCATIONS
12/17/02
RESIDENTIAL SPECIATION LOCATIONS
0 0.25 0.5 0.75 1 Miles

2.0 HISTORICAL and GEOLOGICAL BACKGROUND

History

The El Paso Smelter, was constructed in 1887 as the Consolidated Kansas City Smelting and Refining Company. In 1899 it became part of the newly formed American Smelting and Refining Company (**ASARCO**). It was originally built to process the rich, lead ores from the West, but was later (1910) expanded by adding a copper circuit, primarily for Arizona ores. Later in 1930's ~1950, and 1970's facilities were added for cadmium, zinc, and antimony, respectively.

The lead facility originally consisted of a 100 foot wooden stack and six blast furnaces with associated sintering (4 roasters) capacity to handle some 225,000 tons of charge per year. After the 1902 fire, seven lead furnaces were constructed along with a new 400 foot stack. The lead plant was closed in 1985. (Hydrometrics, 2001)

The copper facility consisted of four Herreshoff roasters, one reverberatory furnace, and three Peirce-Smith converters. Roaster and reverberatory gases are eliminated from a 828 foot stack and the converter gases discharge from a 100 foot stack. Baghouses and electrostatic precipitators (devices used to minimize stack emissions) were introduced to the facility in the early 1900's to limit the loss of metal from fumes. Annual production produced 110,000 tons of anode copper.

In the early 1930's a Godfrey roaster was added for cadmium production and in the 1970's an antimony plant was added.

In 1947 a zinc fuming facility, to treat slags, was added to handle the elevated concentrations of zinc (up to 10 percent Zn) which were being produced when smelting the New Mexico ores.

The furnace treated 20,000 tons of slag per month. In early 1950's a new 600 foot stack was built to handle the lead and zinc facilities.

In the mid 1980's the antimony plants closed followed by a closing of the zinc and cadmium plants in 1992. The smelter still operates its copper (CONTOP) facility which was added in 1993. The plant has been on a mandatory three-year care and maintenance since 1999.

Geology:

El Paso lies the extreme western tip of Texas, within the southern part of the Basin and Range province. The south-east flowing Rio Grande River marks the southern limits of the city and the international boundary between the United States and Mexico. The climate is arid, with annual precipitation averaging only 9 inches. The prevailing winds are westerly, with dust storms a common occurrence in the early months of the year.

The metropolitan area of El Paso lies primarily within the floodplain of the Rio Grande River, once dominated by a large lake bed (Lake Cabeza de Vaca). Millions of years of river deposition resulted in a complex sedimentary sequence of gravel, silt, clay, and sand called the Fort Hancock Formation, accumulating to a thickness of more than 9,000 feet. Recent geological activity has been dominated by Basin and Range tectonics and the emplacement of young, 40,000 year old, basalt flows and cinder cones from the Potrillo Volcanic field. There is nothing in the geological record that could account for the elevated metal (Pb, As, Cu, Cd, Zn) concentration found in the residential soils.

For decades, preceding the construction of dams on the Elephant Butte and Caballo lakes in 1916, spring flood waters would move onto the downtown area of El Paso.

3.0 LEAD and ARSENIC GEOCHEMISTRY

Arsenic is found in many minerals and is typically enriched in soils originating from shales/schists and argillaceous sediments. Lead on the other had is more commonly concentrated in silicic magmatic rocks and argillaceous sediments. Uncontaminated soils have mean concentrations of 1-6 mg/kg for arsenic and 3-19 for lead (Fergusson, 1990), worldwide. The lowest levels are typically found in soils derived from volcanic or carbonate terrain, as are those in the El Paso area (volcanics and limestones), and average 1-7 mg/kg As and 3-14 mg/kg Pb. The arid climate in the El Paso area along with the near neutral (6-8.5 pH) acidity of the local soils stimulate very low metal mobility, generally concentrating metals in the surface horizons by preventing there downward distribution over time. Mobility may be enhanced by irrigation, aeration, or by utilization of soil amendments (Logan and Chaney, 1983).

Numerous sources of lead and/or arsenic can produce elevated concentrations in surface soils. Table 1 is a compilation of the most common sources, their speciation, along with associated soil concentrations (data from Barzi et al., 1996, Kabata and Pendias, 1993; Fergusson, 1990; and Drexler, per. communication, 1998).

Table 1. Compilation of common lead and arsenic sources and associated soil-metal concentrations.

Source	Arsenic Speciation	Associated Soils As mg/kg	Lead Speciation	Associated Soils Pb mg/kg
Paint Pigments			$PbCO_3$, $PbSO_4$, PbO, $PbCrO_4$	100-900
Mining	Sulfosalts, As_2S_3, FeAsS	23-1023	Sulfosalts, PbS, $PbCO_3$, $PbSO_4$	100-96,000
Chemical Works	PbAsO, As_2O_3 ,R**AsO	10-2000	PbAsO, Pb, $PbSO_4$	100-600
Metal Processing	As_2O_3, AsM*O, PbAsO	33-2500	PbM*O, PbAsO , PbO, FePbO, $PbCO_3$, Slag, $PbCl_4$	100-12,000
Application of Pesticides	As_2O_3, PbAsO, R**AsO, Na-Ca arsenates	38-625	PbAsO,	200-2500
Gardens and orchards	PbAsO	38-892	PbAsO	200-2500
Fly Ash	Unknown	1-9		
Municipal Sludge	Unknown	1-6		80-7400
Sheep/Cattle Dip/Tannery	As_2O_3, Na-Ca arsenates	300-1000		
Wood Preservatives	Cr-Cu arsenates	10-2000		

**R = Organic compounds, *M = typically Pb, Ca, Cd, Zn, or Sb.

INTERNAL DRAFT - For Discussio Only

4.0 SPECIATION

Seven samples from the ASARCO facility and twenty-eight samples from the surrounding community (Table 2.) were speciated for lead and arsenic using electron microprobe (EMPA) techniques. Methodologies used for sample preparation, data collection, and data synthesis are described below.

Table 2.0 Speciation sample set.

Cu Lab No.	Source	Cu mg/kg	Zn mg/kg	As mg/kg	Se mg/kg	Cd mg/kg	Sb mg/kg	Pb mg/kg
ELP-1	Front Yard	518	656	74	1.0	22	1.0	1084
ELP-2	Front Yard	379	464	52	ND	14	1.0	448
ELP-3	Front Yard	189	313	66	1.0	6	1.0	236
ELP-4	Front Yard	732	712	60	8.9	22	3.7	979
ELP-5	Back Yard	396	496	40	0.5	11	1.2	400
ELP-6	Front Yard	812	782	59	2.2	27	2.4	789
ELP-7	Front Yard	108	226	17	1.2	3	ND	164
ELP-8	Front Yard	58	229	47	ND	2	1.0	109
ELP-9	Front Yard	931	1038	71	ND	24	2.0	892
ELP-10	Front Yard	802	855	57	0.7	24	2.1	1151
ELP-11	Drip Line	666	559	63	1.6	20	2.0	1046
ELP-12	Back Yard	158	317	12	ND	6	1.0	328
ELP-13	Front Yard	3797	1137	73	ND	21	7.0	939
ELP-14	Front Yard	832	685	60	1.0	18	1.8	1031
ELP-15	Back Yard	568	611	29	ND	20	1.1	754
ELP-16	Front Yard	556	610	97	ND	21	1.5	756
ELP-17	Front Yard	468	468	38	ND	17	0.6	768
ELP-18	Front Yard	536	1061	98	11.0	9	3.1	515
ELP-19	Front Yard	286	860	186	1.6	11	1.8	488
ELP-20	Back Yard	838	770	44	ND	30	2.3	1046
ELP-21	Back Yard	551	718	40	ND	17	1.3	831
ELP-22	Front Yard	321	398	33	ND	11	1.0	408
ELP-30	Front Yard	192	591	14	ND	6	ND	407
ELP-31	Front Yard	213	305	12	ND	6	ND	316
ELP-32	Front Yard	52	98	8	ND	1	ND	108
ELP-33	Front Yard	141	262	13	ND	5	ND	1785
TM	Distal Yard	27	29	4	ND	1	1.0	46
Z-1	Distal Yard	52	169	39	ND	1	1.0	53

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Sample ID.	Cu Lab No.	Source	Cu mg/kg	Zn mg/kg	As mg/kg	Se mg/kg	Cd mg/kg	Sb mg/kg	Pb mg/kg
9600-55-00	ELP-23	Plant	334951	8612	4795	9031	393	773	8244
9605-55-00	ELP-24	Plant	5709	2936	602	16.0	167	15.0	6122
9606-55-00	ELP-25	Plant	183576	67918	24854	11590	6523	1210	9973
9603-55-00	ELP-26	Plant	12198	18643	400	12.0	25	16.0	3397
9602-55-00	ELP-27	Plant	15394	21418	365	11.0	22	19.0	1996
9604-55-00	ELP-28	Plant	1514	729	180	2.0	35	4.0	1312
9601-55-00	ELP-29	Plant	11053	2144	307	8.0	68	13.0	858

4.01 Methodology

Metal speciation was conducted on a JEOL 8600 electron microprobe (EMPA), operating at 15Kv (accelerating voltage) and 15-20 nanoAmps current, at the Laboratory for Geological Studies at the University of Colorado following the laboratory's SOP. For a complete description of the methodology a copy of the SOP is available at our website:

htpp://www.colorado.edu/GeolSci/legs

One exception was made in the SOP, in that the samples were not sieved to <250 μm, as is most common for bioavailability determinations, but the 2mm fraction was used in order to be consistent with previous site studies. The samples were all air dried and prepared for speciation analysis as outlined in the SOP. A combination of both an Energy Dispersive Spectrometer (EDS) and a Wavelength Dispersive Spectrometer (WDS) were used to collect x-ray spectra and determine elemental concentrations on observed mineral phases. All quantitative analyses are based on certified mineral and metal standards using a Phi Rho Z correction procedure. Representative backscatter photomicrographs (BSPM) illustrating sample characteristics were acquired.

Data from EMPA will be summarized using three methods. The first method is the determination of FREQUENCY OF OCCURRENCE (F). This is calculated by summing the longest dimension of all the lead or arsenic-bearing phases observed during the point counting and then dividing each phase by the total length for all phases.

Equation 1.0 will serve as an example of how to calculate the frequency of occurrence for an arsenic- bearing compound, lead-bearing particles are handled in a similar manner.

F_{As} - Frequency of occurrence of arsenic in a single phase.

PLD - An individual particle's longest dimension

$$F_{As} \text{ in phase-1} = \frac{\sum (PLD)_{\text{phase-1}}}{\sum (PLD)_{\text{phase-1}} + \sum (PLD)_{\text{phase-2}} + \sum (PLD)_{\text{phase-n}}} \qquad \text{Eq. 1.0}$$

$$\%F_{As} \text{ in phase-1} = F_{As} \text{ in phase-1} * 100$$

Thus, the frequency of occurrence of arsenic in each phase (F_{As}) is calculated by summing the longest dimension of all particles observed for that phase and then dividing each phase by the total of the longest dimensions for all phases. The data generated thus illustrate which arsenic-bearing phase(s) are the most commonly observed in the sample or relative volume percent.

The second calculation used in this report determines the RELATIVE MASS ARSENIC (RM_{As}) in a phase.

$$RM_{As} \text{ in phase-1} = \frac{\sum (M_{As\cdot})_{\text{phase-1}}}{} \qquad \text{Eq. 2.0}$$

$$\sum (M_{As\cdot})_{phase\text{-}1} + \sum (M_{As\cdot})_{phase\text{-}2} + \sum (M_{As\cdot})_{phase\text{-}n}$$

$$\%RM_{As} \text{ in phase-1} = RM_{As} \text{ in phase-1} * 100$$

M_{As} - Mass of arsenic in a phase
SG - Specific Gravity of a phase

ppm_{As} - Concentration in ppm of arsenic in phase (see Table A1.0, Appendix I)

$$M_{As} = F_{As} * SG * ppm_{As} \qquad \text{Eq. 2.0}$$

The advantage in reviewing the RELATIVE MASS ARSENIC determinations is that it gives one information as to which metal-bearing phase(s) in a sample is likely to control the total bulk concentration for arsenic. As an example, PHASE-1 may, by relative volume, contribute 98% of the sample, however it has a low specific gravity and contains only 1000 ppm arsenic, whereas PHASE-2 contribute 2% of the sample, has a high specific gravity and contains 850000 ppm of arsenic. In this example it is PHASE-2 that is the dominant source of arsenic to the sample.

The third calculation is to determine the MINERAL MASS ARSENIC (Min_{As}). In this calculation the RM_{As} is simply multiplied by the bulk concentration of arsenic found in the sample:

$$Min_{As} = RM_{AS} * As_{Bulk} \qquad \text{Eq. 3.0}$$

Where As_{Bulk} is the bulk arsenic for the sample speciated. These values are most useful for geostatistical calculations, such as kriging, or apportionment since values are not forced to 100%.

4.02 Point Counting

Point counts (weighted on longest dimension) are made by traversing each sample from left-to-right and top-to-bottom. The amount of vertical movement for each traverse would depend on magnification and CRT (cathode-ray tube) size. This movement should be minimized so that NO portion of the sample is missed when the end of a traverse is reached. Two magnification settings should be used. One ranging from 40 to 100X and a second from 300 to 600X. The last setting will allow one to find the smallest identifiable (1-2 micron) phases. The portion of the sample examined in the second pass, under the higher magnification, will depend on the time available, the number of metal-bearing particles, and the complexity of metal mineralogy. A maximum of 8 hours will be spent per sample.

The point counting procedure in petrography is a well established technique as outlined by Chayes, 1949. For our procedure we have simply substituted the electron microprobe for a simple petrographic microscope as a means of visually observing a particle and identifying its composition using the attached x-ray analyzers. The operator error (identification of phase and sizing) is generally negligible. However the particle counting error can be significant depending on the total number of particles counted and the fraction of an individual component (species)

percent. Based on studies in El-Hinnawi, 1966, it was shown that the relative error of a point count based on 100 total particles versus one of 300 total particles is only 10% and 6% , respectively (for a species representing 30% of the count). It is our belief that this small decrease in error is not justified when cost and time of analysis are considered, and that it is much more beneficial to increase your total sample population and address representativeness.

4.03 Precision and Accuracy

The precision of the EMPA speciation will be evaluated based on sample duplicates analyzed at a frequency of 10% as selected by the laboratory, however the client may also submit "blind" duplicates for analyses. The precision of the data generated by the "EMPA point count" will be evaluated by calculating RPD values for all major (>20% frequency) phases, comparing the original result with the duplicate result. If the duplicate analyses are from samples that have produced at least 100 total particles it is expected that all (100%) of the dominant species (representing 60% of frequency) be found in both, and that their individual frequency of occurrence not vary by more than 30%, relative. In the evaluation of the method precision it is most important to consider the variation in results among all samples studied for a particular media, since the overall particle count is very large Data generated by the "EMPA point count" will be further evaluated statistically based on the methods of Mosimann (1965) at the 95% confidence level on the frequency data following Equation 4.

$$E_{0.95} = 2P(100-P)/N \qquad \text{(Eq. 4)}$$

Where: $E_{0.95}$ = Probable error at the 95% confidence level

P = Percentage of N of an individual metal-bearing phase based on percent length frequency

N = Total number of metal-bearing grains counted

Accuracy of quantitative metal analyses on non-stoichimetric metal phases is based on established EMPA procedures, and data reduction, Heinrich, 1981 and is generally 1-2% relative. All quantitative analyses will be performed using a series of certified mineral standards. In general, site-specific concentrations for these variable, metal-bearing forms will be determined by performing "peak counts" on the appropriate wavelength spectrometer. Average concentrations will then be used for further calculations. Data on specific gravity will be collected from referenced databases or estimated based on similar compounds.

Plant-site Samples

During the 116 year operational history of the ASARCO facility, numerous sources for heavy-metal emissions existed, including:

Roasters, blast furnaces

Storage piles

Plant road dust

Loading/unloading facilities

Baghouses/dust collectors

Few of these sources are available today for direct sampling, therefore, plant-site samples were limited. In terms of the historical speciation of lead and arsenic at the plant, these samples are most certainly incomplete. Thus these samples provide only a partial "source fingerprint".

Approximately 2100 particles containing either lead or arsenic were counted in the six soil samples from the ASARCO plant, Table 3. These samples can be generally characterized as representing three distinct media at the site; 1) a slag-rich (ELP 26,27) 2) a copper circuit (ELP 25) and 3) general plant soil (ELP 28,29). As a whole, plant samples studied to date have lead masses dominated (78% of the relative lead mass) by the following lead-bearing phases: PbS, $PbMSO_4$, $CuMSO_4$, $CrMSO_4$, PbAsO, and PbO Figure 2, Photos 1-3. The most common metals "M" are As, Sb or Cd. Arsenic masses dominated (85% of the relative arsenic mass) by the following arsenic-bearing phases: $CuMSO_4$, CuM, PbAsO, and $PbMSO_4$ Figure 2, Photos 1-3.

The most common metals "M" are Pb or Sb. These primary phases are consistent with the facilities operations.

Particle size of lead and arsenic phases are trimodal in their distribution with populations at 2,10 and 100 microns, Figure 3. The 2 micron population is dominated by PbS, the 10 micron by $CuMSO_4$, and the coarser, 100+ micron population by slag.

Each of the plant samples show unique lead and arsenic speciation and the site summary, Figure 2, is dominated by a large number of CuM and $CuMSO_4$ particles that are only found in two of the samples. If one would exclude those two samples, the dominant species of lead would be PbS, PbO, $PbMSO_4$, and PbAsO while arsenic would be primarily found in PbAsO, $PbMSO_4$, and sulfosalts species.

Table 3

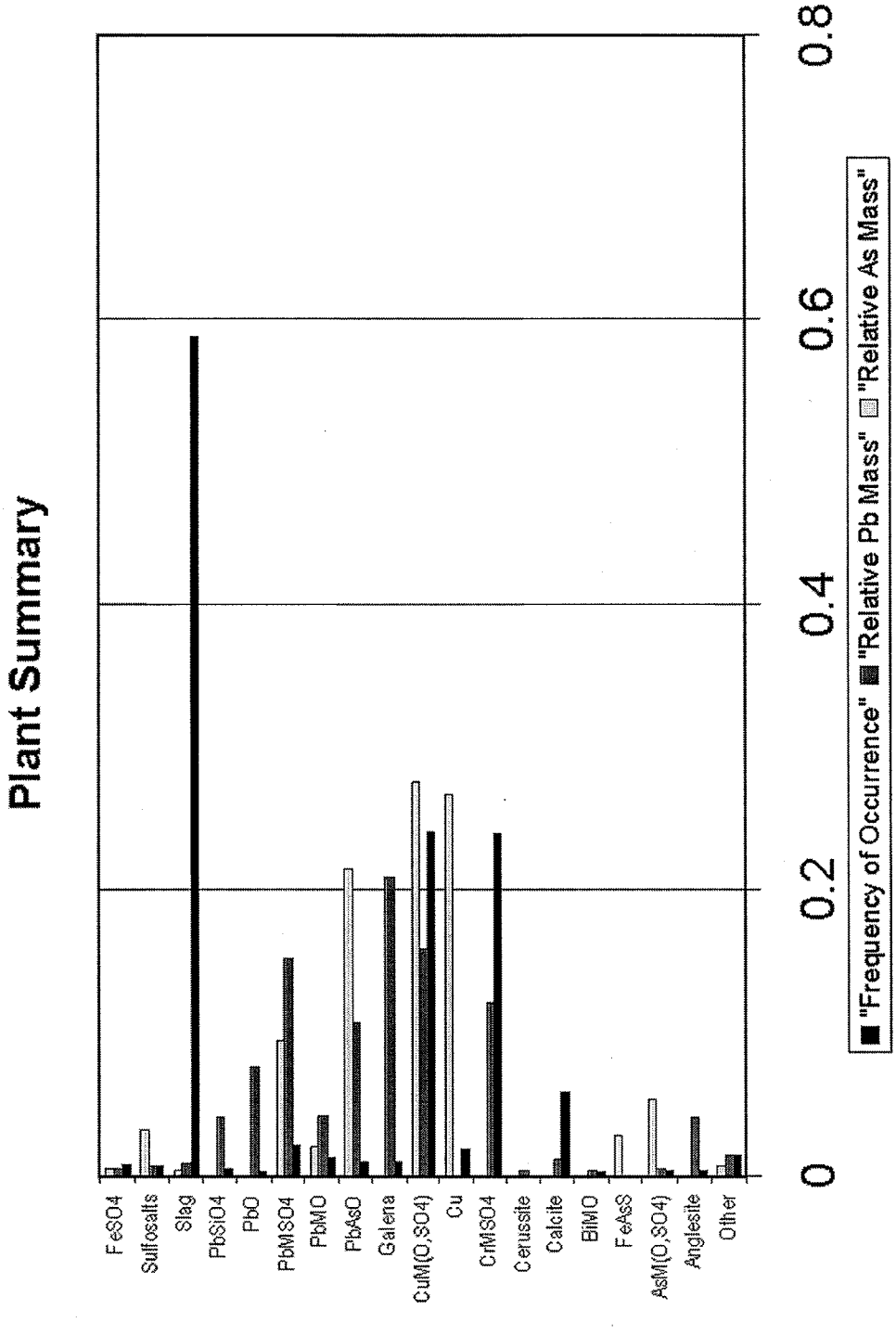
TABLE 3. Summary Plant Speciation Analyses.

		F%	RM-Pb	RM-As	E-95*	Min-Pb	Min-As
ELP-23	BiMO	5.18%	1.83%	0.05%	2.56%	214	2
	Cerussite	0.46%	1.85%	0.00%	0.78%	216	0
	Cu	55.97%	0.39%	91.22%	5.74%	46	4659
	CuMO	7.95%	1.35%	1.31%	3.13%	157	67
	Galena	10.60%	53.96%	0.00%	3.56%	6309	0
	PbAsO	0.46%	1.28%	1.20%	0.78%	150	61
	PbMO	4.03%	7.05%	1.25%	2.28%	824	64
	PbMSO4	6.14%	10.10%	2.95%	2.78%	1181	151
	PbO	1.73%	11.97%	0.00%	1.51%	1399	0
	PbSiO4	3.84%	9.03%	0.06%	2.22%	1056	3
	Phosphate	0.31%	0.33%	0.03%	0.64%	39	1
	(Sb,Sn)MO	0.12%	0.03%	0.00%	0.39%	3	0
	Sulfosalts	3.53%	0.83%	1.94%	2.14%	97	99
ELP-24	Clay	0.12%	0.04%	0.03%	0.43%	3	0
	Anglesite	0.47%	5.11%	0.00%	0.84%	422	0
	AsFeO	0.18%	0.10%	1.21%	0.52%	8	10
	AsMO	0.60%	0.65%	11.94%	0.94%	54	100
	Calcite	75.64%	11.75%	0.63%	5.23%	971	5
	CuMO	0.12%	0.07%	0.17%	0.43%	5	1
	FeOOH	3.70%	1.06%	0.71%	2.30%	87	6
	MnOOH	0.52%	0.98%	0.11%	0.88%	81	1
	PbAsO	2.72%	24.18%	59.86%	1.98%	1998	502
	PbFeOOH	1.50%	3.68%	4.68%	1.48%	304	39
	PbMO	2.51%	13.99%	6.56%	1.90%	1156	55
	PbMSO4	2.03%	10.68%	8.26%	1.72%	882	69
	PbO	0.47%	10.48%	0.00%	0.84%	866	0
	PbSiO4	2.06%	15.50%	0.29%	1.73%	1280	2
	Phosphate	0.05%	0.16%	0.04%	0.26%	13	0
	Pyrite	0.37%	0.01%	0.34%	0.74%	1	3
	(Sb,Sn)MO	4.22%	0.03%	0.01%	0.26%	3	0
	Slag	0.05%	0.05%	0.02%	2.45%	4	0
	Sulfosalts	0.87%	0.67%	4.12%	1.14%	55	35
	FeSO4	1.77%	0.84%	1.02%	1.61%	69	9

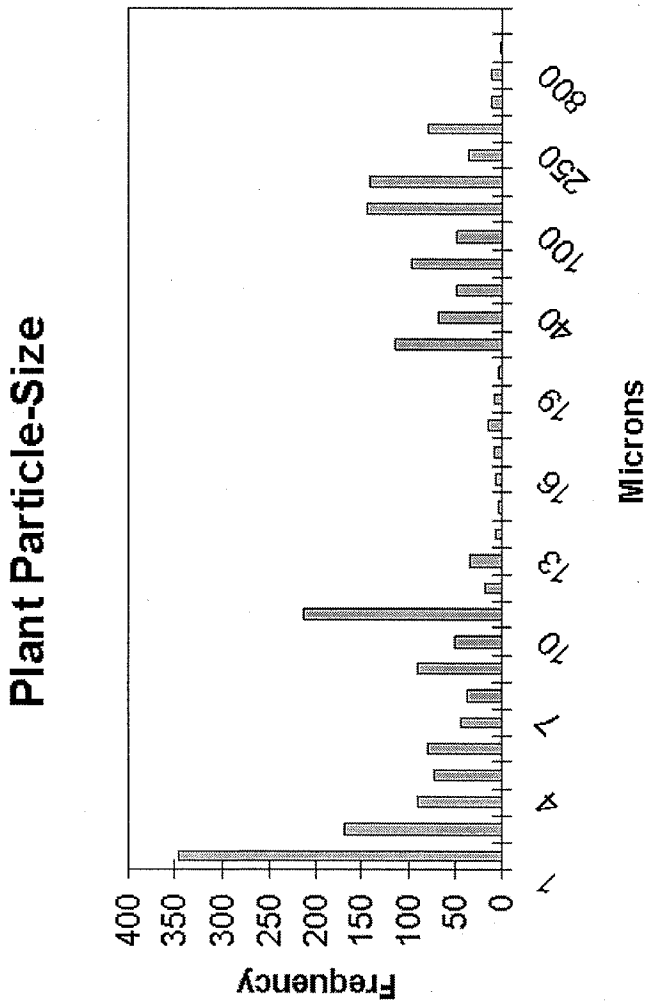
ELP-25	Anglesite	0.09%	1.25%	0.00%	0.29%	655	0
	AsMSO4	0.02%	0.09%	0.21%	0.13%	47	50
	BiMO	0.01%	0.02%	0.00%	0.12%	11	0
	CrMSO4	1.61%	0.82%	0.00%	1.25%	432	0
	Cu	0.30%	0.01%	3.38%	0.54%	5	809
	CuMSO4	91.92%	61.31%	79.19%	2.71%	32193	18953
	PbAsO	0.02%	0.27%	0.40%	0.15%	142	96
	PbAsVO	0.04%	0.43%	0.01%	0.19%	225	3
	PbMSO4	5.01%	35.74%	16.63%	2.17%	18769	3981
	Slag	0.94%	0.01%	0.00%	0.96%	7	1
	Sulfosalts	0.04%	0.05%	0.17%	0.21%	24	41
ELP-26	Anglesite	1.01%	22.22%	0.00%	1.14%	506	0
	CuMO	0.13%	0.14%	2.27%	0.41%	3	8
	Galena	1.61%	53.06%	0.00%	1.43%	1209	0
	PbAsO	0.07%	1.29%	19.88%	0.30%	29	73
	PbMO	0.01%	0.16%	0.47%	0.14%	4	2
	PbMSO4	0.97%	10.36%	49.92%	1.11%	236	182
	PbO	0.22%	9.94%	0.00%	0.53%	227	0
	Slag	95.41%	2.10%	6.07%	2.38%	48	22
	Sulfosalts	0.34%	0.51%	19.74%	0.66%	12	72
	FeSO4	0.23%	0.22%	1.66%	0.54%	5	6
ELP-27	CuMO	0.03%	0.11%	1.71%	0.15%	2	6
	Galena	0.59%	72.30%	0.00%	0.69%	1445	0
	PbMO	0.07%	2.94%	8.02%	0.24%	59	28
	PbMSO4	0.02%	0.77%	3.49%	0.13%	15	12
	PbO	0.08%	13.98%	0.00%	0.26%	280	0
	Slag	98.89%	8.08%	21.82%	0.94%	162	75
	Sulfosalts	0.32%	1.80%	64.96%	0.51%	36	223

*E-95= Estimated counting error at 95% confidence level, Mosiann, 1965.

ELP-28	Clay	10.10%	1.19%	0.74%	1.59%	27	2
	Anglesite	1.18%	4.63%	0.00%	3.09%	106	0
	AsMO	3.00%	1.18%	17.56%	1.59%	27	57
	Arsenopyrite	0.77%	0.00%	9.66%	0.00%	0	31
	CuMO	0.41%	0.08%	0.17%	0.42%	2	1
	FeOOH	10.32%	1.07%	0.58%	1.51%	25	2
	Galena	3.41%	20.14%	0.00%	5.89%	462	0
	PbAsO	9.14%	29.50%	58.77%	6.70%	677	190
	PbFeOOH	2.18%	1.94%	1.99%	2.03%	45	6
	PbMO	4.05%	8.20%	3.10%	4.03%	188	10
	PbMSO4	2.73%	5.20%	3.24%	3.26%	119	10
	PbO	2.59%	20.82%	0.00%	5.96%	478	0
	PbSiO4	1.46%	3.97%	0.06%	2.87%	91	0
	Pyrite	5.18%	0.03%	1.41%	0.26%	1	5
	(Sb,Sn)MO	0.14%	0.04%	0.01%	0.28%	1	0
	Slag	32.88%	0.13%	0.05%	0.53%	3	0
	Sulfosalts	0.77%	0.21%	1.05%	0.67%	5	3
	FeSO4	9.69%	1.66%	1.62%	1.88%	38	5
ELP-29	Anglesite	1.16%	3.58%	0.00%	2.54%	48	0
	AsFeO	1.78%	0.27%	1.90%	0.71%	4	6
	AsMO	3.61%	1.12%	11.66%	1.44%	15	38
	Arsenopyrite	1.56%	0.00%	10.76%	0.00%	0	35
	BiMO	2.23%	0.72%	0.03%	1.16%	10	0
	Cerussite	0.09%	0.33%	0.00%	0.78%	4	0
	CuMO	2.77%	0.43%	0.62%	0.89%	6	2
	FeOOH	8.97%	0.73%	0.28%	1.17%	10	1
	Galena	1.61%	7.47%	0.00%	3.60%	101	0
	Native Pb	0.13%	1.08%	0.00%	1.42%	15	0
	PbAsO	16.47%	41.86%	58.36%	6.75%	566	188
	PbMO	1.38%	2.21%	0.58%	2.01%	30	2
	PbMSO4	10.66%	16.02%	6.98%	5.02%	217	22
	PbO	1.12%	7.06%	0.00%	3.51%	95	0
	PbSiO4	3.57%	7.67%	0.08%	3.64%	104	0
	Phosphate	6.07%	6.00%	0.76%	3.25%	81	2
	Pyrite	1.74%	0.01%	0.26%	0.13%	0	1
	(Sb,Sn)MO	0.13%	0.03%	0.01%	0.23%	0	0
	Slag	15.39%	0.05%	0.01%	0.30%	1	0
	Sulfosalts	9.01%	1.94%	6.75%	1.89%	26	22
	FeSO4	10.53%	1.42%	0.97%	1.62%	19	3


Plant Summary
FeSO4
Sulfosalts
Slag
PbSiO4
PbO
PbMSO4
PbMO
PbAsO
Galena
CuM(O,SO4)
Cu
CrMSO4
Cerussite
Calcite
BiMO
FeAsS
AsM(O,SO4)
Anglesite
Other
0
0.2
0.4
0.6
0.8
"Frequency of Occurrence"
"Relative Pb Mass"
"Relative As Mass"

27 Fig2


Plant Particle-Size
Frequency
400
350
300
250
200
150
100
50
0
1
4
7
10
13
16
19
40
100
250
800
Microns

28 Fig3

Community Soils

Community soil sample set (Figure 1) includes soils with varied bulk lead and arsenic concentrations 46-1785 mg/kg, and 4-186 mg/kg, respectively. From these samples over 2400 lead and or arsenic bearing particles were counted, Table 4. These data indicate that slag, iron oxide and phosphate are the most commonly found lead/arsenic-bearing phases in the residential soils. However, lead masses almost exclusively (84% of the relative lead mass) are dominated by phosphate, PbS, PbAsO, PbMO, $PbCO_3$, $PbMSO_4$, and $PbSO_4$, with minor contributions from other lead forms, Figure 4. Five of these six dominant forms of lead are consistent with those found at the ASARCO facility and three of the five forms could only be associated with a pyrometalurgical facility. Arsenic masses almost exclusively (85% of the relative arsenic mass) dominated by arsenopyrite, PbAsO, AsMO, $PbMSO_4$ and phosphate, Figure 4, Photos 4-11. Again, three of the four dominant forms of arsenic in community soils are consistent with ASARCO facility speciation results and two of the three could only be associated with a pyrometalurgical facility. Approximately 62% of the residential yards had apportionable lead paint, however, only 12% of those yards had paint as a dominant lead phase. No evidence morphological, demographical, or mineralogical could be established to support lead or arsenic contributions from either pesticides or herbicides.

The particle- size distribution for all lead and arsenic species is bimodal, at approximately 2 and 40 microns, Figure 5. The 2 micron size population is not dominated by a particular phase, however, the coarser (40 micron) population is composed in general of liberated, slag grains.

Table 4

TABLE 4. Summary of Residential Speciation Analyses.

		F%	RM-Pb	RM-As	E-95*	Min-Pb	Min-As
ELP-9	Clay	2.61%	0.73%	0.97%	3.19%	6	1
	AsFeOOH	0.97%	0.44%	9.49%	1.96%	4	6
	FeOOH	27.22%	6.68%	7.76%	8.90%	57	5
	Galena	0.22%	3.13%	0.00%	0.95%	27	0
	Paint	3.36%	1.95%	0.00%	3.60%	17	0
	PbAsO	0.60%	4.56%	19.48%	1.54%	39	13
	PbM(Cl,SO,O)	5.37%	25.77%	20.87%	4.51%	219	14
	PbMSO4	2.98%	13.47%	17.99%	3.40%	114	12
	Phosphate	13.42%	39.87%	15.44%	6.82%	339	10
	SbMO	0.82%	0.53%	0.34%	1.80%	4	Tr
	Slag	36.39%	0.34%	0.27%	9.62%	3	Tr
	Sulfosalts	0.37%	0.24%	2.57%	1.22%	2	2
	FeMSO4	5.67%	2.30%	4.82%	4.63%	20	3
ELP-8	Anglesite	2.33%	8.03%	0.00%	4.67%	10	0
	AsFeOOH	3.10%	0.52%	1.70%	5.37%	1	1
	Arsenopyrite	26.74%	0.00%	95.17%	13.72%	0	54
	FeOOH	13.57%	1.24%	0.22%	10.61%	1	Tr
	Galena	16.67%	86.77%	0.00%	11.55%	105	0
	PbM(Cl,SO,O)	0.39%	0.69%	0.08%	1.93%	1	Tr
	PbMSO4	0.78%	1.30%	0.26%	2.72%	2	Tr
	Pyrite	27.91%	0.15%	2.16%	13.90%	Tr	1
	FeMSO4	8.53%	1.29%	0.41%	8.66%	2	Tr
ELP-7	Anglesite	0.90%	4.69%	0.00%	3.62%	8	0
	AsMO	2.24%	1.18%	10.90%	5.69%	2	2
	Arsenopyrite	6.28%	0.00%	65.18%	9.32%	0	10
	Galena	0.45%	3.53%	0.00%	2.57%	6	0
	PbMSO4	13.45%	34.25%	13.27%	13.12%	57	2
	Phosphate	29.60%	49.57%	5.57%	17.55%	82	1
	Pyrite	4.48%	0.04%	1.01%	7.96%	Tr	Tr
	Slag	13.45%	0.07%	0.02%	13.12%	Tr	Tr
	FeMSO4	29.15%	6.67%	4.06%	17.47%	11	1

ELP-6	Anglesite	8.82%	33.35%	0.00%	4.86%	279	0
	AsMO	0.86%	0.33%	16.36%	1.58%	3	9
	CuM(SO,O)	2.77%	0.58%	0.00%	2.81%	5	0
	FeOOH	9.17%	0.92%	1.68%	4.94%	8	1
	Galena	4.08%	23.26%	0.00%	3.39%	195	0
	Paint	16.89%	4.00%	0.00%	6.42%	34	0
	PbAsO	1.66%	5.18%	34.91%	2.19%	43	20
	PbFeOOH	1.11%	0.95%	3.30%	1.79%	8	2
	PbM(Cl,SO,O)	2.27%	4.44%	5.67%	2.55%	37	3
	PbMSO4	6.75%	12.43%	26.17%	4.30%	104	15
	Phosphate	11.04%	13.36%	8.16%	5.37%	112	5
	Slag	27.97%	0.11%	0.13%	7.69%	1	Tr
	FeMSO4	6.60%	1.09%	3.61%	4.25%	9	2
ELP-5	Anglesite	1.99%	9.98%	0.00%	3.53%	39	0
	AsFeOOH	2.99%	0.73%	6.45%	4.31%	3	3
	AsMO	2.24%	1.13%	14.69%	3.74%	4	6
	Arsenopyrite	3.48%	0.00%	48.80%	4.64%	0	20
	Cerussite	0.25%	1.48%	0.00%	1.26%	6	0
	CuM(SO,O)	1.74%	0.49%	0.00%	3.31%	2	0
	FeOOH	41.79%	5.54%	2.63%	12.48%	22	1
	Galena	3.48%	26.32%	0.00%	4.64%	102	0
	PbAsO	2.74%	11.30%	19.73%	4.13%	44	8
	PbM(Cl,SO,O)	1.49%	3.87%	1.28%	3.07%	15	1
	Phosphate	24.13%	38.75%	6.13%	10.83%	150	2
	Slag	12.19%	0.06%	0.02%	8.28%	Tr	Tr
	FeMSO4	1.49%	0.33%	0.28%	3.07%	1	Tr
ELP-4	Clay	2.88%	0.63%	0.66%	2.95%	6	Tr
	FeOOH	9.63%	1.85%	1.71%	5.21%	17	1
	MnOOH	1.66%	2.10%	0.33%	2.26%	20	Tr
	Organic	7.75%	0.34%	0.01%	4.72%	3	Tr
	PbAsO	3.65%	21.88%	74.24%	3.32%	204	38
	PbFeOOH	0.72%	1.19%	2.08%	1.49%	11	1
	PbM(Cl,SO,O)	0.17%	0.62%	0.40%	0.72%	6	Tr
	PbSiO4	1.33%	6.72%	0.17%	2.02%	63	Tr
	Phosphate	27.50%	64.04%	19.69%	7.89%	597	10
	Slag	43.77%	0.32%	0.20%	8.77%	3	Tr
	FeMSO4	0.94%	0.30%	0.50%	1.71%	3	Tr

ELP-3	AsFeOOH	0.40%	0.43%	0.44%	2.09%	1	Tr
	Arsenopyrite	13.50%	0.00%	95.30%	11.32%	0	45
	FeOOH	23.93%	13.80%	0.76%	14.14%	30	Tr
	Galena	0.67%	21.97%	0.00%	2.70%	48	0
	MnOOH	2.81%	10.65%	0.10%	5.47%	23	Tr
	PbMSO4	0.27%	2.84%	0.18%	1.71%	6	Tr
	Phosphate	6.42%	44.81%	0.82%	8.12%	97	Tr
	Pyrite	11.10%	0.38%	1.70%	10.41%	1	1
	Slag	36.63%	0.80%	0.03%	15.96%	2	Tr
	Sulfosalts	0.40%	0.61%	0.31%	2.09%	1	Tr
	FeMSO4	3.88%	3.70%	0.37%	6.40%	8	Tr
ELP-22	AsFeOOH	0.58%	0.35%	4.59%	1.97%	1	1
	Arsenopyrite	1.16%	0.00%	59.50%	2.78%	0	19
	FeOOH	27.06%	8.88%	6.23%	11.53%	34	2
	MnOOH	1.63%	3.51%	0.42%	3.28%	13	Tr
	PbAsO	0.23%	2.37%	6.12%	1.25%	9	2
	Phosphate	20.67%	82.16%	19.19%	10.51%	313	6
	Pyrite	1.28%	0.03%	1.42%	2.92%	Tr	Tr
	SbMO	0.58%	0.50%	0.19%	1.97%	2	Tr
	Slag	43.79%	0.54%	0.26%	12.88%	2	Tr
	FeMSO4	3.02%	1.64%	2.07%	4.44%	6	1
ELP-21	Anglesite	0.44%	1.76%	0.00%	1.34%	14	0
	AsFeOOH	2.81%	0.55%	5.17%	3.34%	4	2
	AsMO	0.89%	0.35%	4.96%	1.90%	3	2
	Arsenopyrite	2.81%	0.00%	33.53%	3.34%	0	14
	FeOOH	20.12%	2.11%	1.08%	8.10%	17	Tr
	Galena	3.55%	21.22%	0.00%	3.74%	174	0
	Paint	6.36%	1.58%	0.00%	4.93%	13	0
	PbAsO	5.92%	19.33%	36.31%	4.77%	158	15
	PbFeOOH	1.18%	1.07%	1.03%	2.19%	9	Tr
	PbM(Cl,SO,O)	2.81%	5.77%	2.05%	3.34%	47	1
	PbMSO4	7.69%	14.85%	8.72%	5.39%	121	4
	PbSiO4	1.18%	3.27%	0.05%	2.19%	27	Tr
	Phosphate	19.38%	24.61%	4.19%	7.99%	201	2
	Pyrite	0.44%	0.00%	0.12%	1.34%	0	Tr
	SbMO	2.51%	0.69%	0.20%	3.17%	6	Tr
	Slag	5.62%	0.02%	0.01%	4.66%	Tr	Tr
	FeMSO4	16.27%	2.83%	2.60%	7.46%	23	1

ELP-20	Anglesite	0.82%	4.94%	0.00%	1.51%	57	0
	AsMO	5.60%	3.41%	59.09%	3.85%	40	26
	CuM(SO,O)	9.63%	3.24%	0.00%	4.94%	38	0
	FeOOH	32.05%	5.13%	3.24%	7.81%	60	1
	Galena	1.40%	12.77%	0.00%	1.97%	148	0
	Paint	11.97%	4.53%	0.00%	5.44%	53	0
	PbAsO	1.75%	8.72%	20.29%	2.20%	101	9
	PbM(Cl,SO,O)	4.32%	13.51%	5.96%	3.40%	157	3
	PbMSO4	0.58%	1.72%	1.25%	1.28%	20	1
	Phosphate	20.61%	39.90%	8.41%	6.77%	464	4
	SbMO	1.93%	0.81%	0.28%	2.30%	9	Tr
	Slag	4.50%	0.03%	0.01%	3.47%	Tr	Tr
	FeMSO4	4.85%	1.28%	1.46%	3.60%	15	1
ELP-19	Arsenopyrite	12.30%	0.00%	85.12%	9.60%	0	163
	FeOOH	12.94%	2.30%	0.40%	9.81%	12	1
	Galena	3.24%	32.78%	0.00%	5.17%	173	0
	PbFeOOH	6.47%	9.90%	3.27%	7.19%	52	6
	PbM(Cl,SO,O)	2.27%	7.88%	0.96%	4.35%	42	2
	PbMSO4	3.88%	12.71%	2.55%	5.64%	67	5
	Phosphate	12.30%	26.47%	1.54%	9.60%	140	3
	Pyrite	21.68%	0.23%	3.26%	12.04%	1	6
	SbMO	1.29%	0.61%	0.06%	3.30%	3	Tr
	Sulfosalts	0.97%	0.45%	0.73%	2.86%	2	1
	FeMSO4	22.65%	6.67%	2.10%	12.23%	35	4
ELP-18	Arsenopyrite	3.75%	0.00%	70.06%	4.45%	0	46
	CuM(SO,O)	0.26%	0.25%	0.00%	1.20%	2	0
	FeOOH	12.48%	5.75%	1.05%	7.74%	35	1
	Galena	0.07%	1.73%	0.00%	0.60%	10	0
	Paint	1.84%	2.01%	0.00%	3.15%	12	0
	PbAsO	1.45%	20.75%	13.91%	2.80%	125	9
	PbFeOOH	1.31%	5.21%	1.80%	2.67%	31	1
	PbM(Cl,SO,O)	0.85%	7.70%	0.98%	2.16%	46	1
	PbMSO4	5.58%	47.36%	9.93%	5.38%	286	7
	PbO	0.20%	7.04%	0.00%	1.04%	43	0
	Phosphate	0.07%	0.37%	0.02%	0.60%	2	Tr
	Pyrite	4.73%	0.13%	1.92%	4.97%	1	1
	Slag	66.16%	1.16%	0.15%	11.08%	7	Tr
	FeMSO4	0.72%	0.55%	0.18%	1.98%	3	Tr

ELP-17	AsFeOOH	0.09%	0.03%	0.71%	0.56%	Tr	Tr
	AsMO	0.27%	0.17%	6.44%	0.97%	2	3
	Barite	0.27%	0.08%	0.00%	0.97%	1	0
	Cerussite	0.18%	1.37%	0.00%	0.79%	13	0
	Cr	28.60%	6.24%	0.00%	8.33%	59	0
	CuM(SO,O)	0.09%	0.03%	0.00%	0.56%	0	0
	FeOOH	33.73%	5.59%	7.58%	8.72%	53	3
	Galena	0.09%	0.87%	0.00%	0.56%	8	0
	PbAsO	1.56%	8.04%	40.10%	2.28%	76	18
	PbAsVO	2.66%	13.61%	1.54%	2.97%	129	1
	PbFeOOH	1.19%	1.70%	4.35%	2.00%	16	2
	PbM(Cl,SO,O)	4.31%	13.97%	13.19%	3.74%	132	6
	PbMSO4	0.73%	2.24%	3.48%	1.57%	21	2
	Solder	0.18%	0.12%	0.00%	0.79%	1	Tr
	Phosphate	22.36%	44.88%	20.27%	7.68%	425	9
	SbMO	0.37%	0.16%	0.12%	1.11%	2	Tr
	FeMSO4	3.30%	0.91%	2.21%	3.29%	9	1
ELP-16	Anglesite	0.86%	4.05%	0.00%	1.61%	37	0
	AsFeOOH	7.26%	1.67%	12.99%	4.51%	15	14
	AsMO	2.34%	1.11%	12.70%	2.63%	10	14
	Arsenopyrite	1.48%	0.00%	17.13%	2.10%	0	19
	CuM(SO,O)	0.62%	0.16%	0.00%	1.36%	1	0
	FeOOH	23.74%	2.95%	1.24%	7.40%	27	1
	Galena	1.72%	12.20%	0.00%	2.26%	111	0
	MnOOH	0.62%	0.50%	0.04%	1.36%	5	Tr
	PbAsO	6.03%	23.34%	35.98%	4.14%	213	40
	PbAsVO	0.86%	3.31%	0.12%	1.61%	30	Tr
	PbFeOOH	4.31%	4.61%	3.65%	3.53%	42	4
	PbM(Cl,SO,O)	9.84%	23.94%	6.99%	5.18%	218	8
	PbMSO4	5.29%	12.10%	5.83%	3.89%	110	6
	Phosphate	4.80%	7.22%	1.01%	3.72%	66	1
	Pyrite	1.72%	0.01%	0.43%	2.26%	Tr	Tr
	SbMO	1.11%	0.36%	0.08%	1.82%	3	Tr
	Slag	15.87%	0.07%	0.02%	6.35%	1	Tr
	FeMSO4	11.56%	2.38%	1.80%	5.56%	22	2
ELP-15	AsFeOOH	1.75%	0.28%	6.50%	2.60%	2	2

	FeOOH	20.26%	1.73%	2.18%	7.96%	14	1
	Galena	8.61%	41.97%	0.00%	5.55%	337	0
	PbAsO	4.63%	12.32%	57.12%	4.16%	99	18
	PbFeOOH	4.15%	3.05%	7.27%	3.95%	25	2
	PbM(Cl,SO,O)	3.67%	6.14%	5.39%	3.72%	49	2
	PbMSO4	2.23%	3.51%	5.09%	2.93%	28	2
	PbO	0.32%	2.11%	0.00%	1.12%	17	0
	Phosphate	25.52%	26.42%	11.10%	8.63%	212	3
	SbMO	12.12%	0.11%	0.07%	1.37%	1	Tr
	Slag	0.48%	0.04%	0.03%	6.46%	Tr	Tr
	FeMSO4	16.27%	2.30%	5.24%	7.31%	18	2
ELP-14	Clay	2.43%	0.39%	0.30%	2.54%	4	Tr
	AsFeOOH	0.47%	0.12%	1.52%	1.13%	1	1
	AsMO	1.31%	0.69%	12.90%	1.88%	8	9
	CuM(SO,O)	0.28%	0.08%	0.00%	0.87%	1	0
	FeOOH	26.07%	3.63%	2.47%	7.25%	40	2
	MnOOH	16.45%	15.05%	1.76%	6.12%	168	1
	PbAsO	4.58%	19.84%	49.63%	3.45%	221	34
	PbFeOOH	0.93%	1.11%	1.43%	1.58%	12	1
	PbM(Cl,SO,O)	9.44%	25.68%	12.18%	4.83%	287	8
	PbMSO4	2.06%	5.26%	4.11%	2.34%	59	3
	Phosphate	14.39%	24.24%	5.49%	5.79%	270	4
	Slag	5.89%	0.03%	0.01%	3.89%	Tr	Tr
	Sulfosalts	1.87%	0.68%	4.28%	2.24%	8	3
	FeMSO4	13.83%	3.19%	3.91%	5.70%	36	3
ELP-13	Clay	0.09%	0.11%	0.14%	0.47%	1	Tr
	Anglesite	0.11%	4.58%	0.00%	0.52%	42	0
	AsMO	0.02%	0.07%	2.02%	0.20%	1	1
	CuM(SO,O)	0.30%	0.67%	0.00%	0.85%	6	0
	FeOOH	0.72%	0.78%	0.87%	1.33%	7	1
	Galena	0.21%	12.83%	0.00%	0.72%	117	0
	MnOOH	0.07%	0.51%	0.10%	0.42%	5	Tr
	PbAsO	0.02%	0.54%	2.22%	0.20%	5	1
	PbFeOOH	0.50%	4.62%	9.77%	1.10%	42	6
	PbM(Cl,SO,O)	0.17%	3.56%	2.77%	0.64%	32	2
	PbMSO4	2.74%	54.66%	70.31%	2.56%	498	46
	Phosphate	0.89%	11.64%	4.34%	1.47%	106	3
	Pyrite	0.06%	0.00%	0.33%	0.37%	Tr	Tr
	Slag	93.25%	3.82%	2.95%	3.94%	35	2
	Sulfosalts	0.04%	0.11%	1.17%	0.31%	1	1
	FeMSO4	0.83%	1.49%	3.01%	1.43%	14	2
ELP-12	Anglesite	0.93%	3.43%	0.00%	2.68%	13	0

	AsFeOOH	0.79%	0.14%	15.46%	2.49%	1	2
	AsMO	0.40%	0.15%	23.46%	1.76%	1	3
	FeOOH	8.21%	0.80%	4.65%	3.78%	3	1
	Galena	1.46%	8.13%	0.00%	7.69%	31	0
	MnOOH	2.78%	1.79%	1.78%	3.36%	7	Tr
	Paint	67.55%	37.24%	0.00%	4.60%	140	0
	PbAsO	0.26%	0.81%	17.19%	13.11%	3	2
	PbM(Cl,SO,O)	0.26%	0.51%	2.05%	1.44%	2	Tr
	PbMSO4	0.93%	1.67%	11.11%	1.44%	6	2
	Phosphate	7.42%	8.79%	16.95%	2.68%	33	2
	Slag	6.62%	0.02%	0.10%	7.34%	Tr	Tr
	Sulfosalts	0.53%	0.14%	7.26%	6.96%	1	1
	Brass	1.85%	0.00%	0.02%	2.03%	Tr	Tr
ELP-11	Clay	1.81%	0.31%	0.31%	2.25%	4	Tr
	Anglesite	0.50%	2.82%	0.00%	1.19%	32	0
	AsMO	1.71%	0.97%	23.41%	2.18%	11	15
	CuM(SO,O)	0.20%	0.06%	0.00%	0.76%	1	0
	FeOOH	40.96%	6.09%	5.39%	8.30%	70	3
	MnOOH	4.12%	4.03%	0.61%	3.35%	46	Tr
	Paint	6.22%	2.19%	0.00%	4.08%	25	0
	PbAsO	2.91%	13.49%	43.88%	2.84%	154	27
	PbFeOOH	1.31%	1.67%	2.79%	1.91%	19	2
	PbM(Cl,SO,O)	3.11%	9.06%	5.58%	2.93%	104	3
	Solder	1.41%	0.84%	0.02%	1.99%	10	Tr
	Phosphate	32.13%	57.86%	17.05%	7.88%	661	11
	Slag	1.20%	0.01%	0.00%	1.84%	Tr	Tr
	FeMSO4	2.41%	0.59%	0.95%	2.59%	7	1
ELP-10	AsFeOOH	0.41%	0.15%	1.92%	1.52%	1	1
	AsMO	1.22%	0.90%	17.50%	2.63%	8	10
	Arsenopyrite	0.20%	0.00%	6.23%	1.08%	0	3
	CuM(SO,O)	0.51%	0.21%	0.00%	1.70%	2	0
	FeOOH	27.26%	5.30%	3.75%	10.66%	45	2
	Galena	0.31%	3.38%	0.00%	1.32%	29	0
	Paint	23.60%	10.86%	0.00%	10.17%	93	0
	PbAsO	2.03%	12.31%	32.04%	3.38%	105	18
	PbFeOOH	5.19%	8.68%	11.60%	5.31%	74	6
	PbM(Cl,SO,O)	7.02%	26.67%	13.16%	6.12%	228	7
	PbMSO4	0.81%	2.91%	2.37%	2.15%	25	1
	InMS	0.20%	0.01%	0.00%	1.08%	Tr	Tr
	Phosphate	10.68%	25.12%	5.92%	7.40%	215	3
	Pyrite	0.81%	0.01%	0.54%	2.15%	Tr	Tr
	Slag	9.16%	0.07%	0.03%	6.91%	1	Tr
	Sulfosalts	0.20%	0.10%	0.68%	1.08%	1	Tr

	FeMSO4	10.38%	3.34%	4.26%	7.30%	28	2
ELP-1	AsCaO	7.09%	0.52%	41.35%	4.39%	5	27
	AsMO	3.72%	1.96%	23.37%	3.24%	20	15
	FeOOH	27.37%	3.79%	1.65%	2.26%	38	1
	Galena	1.77%	13.98%	0.00%	7.64%	141	0
	MnOOH	1.42%	1.29%	0.10%	2.26%	13	Tr
	Paint	4.43%	1.45%	0.00%	2.02%	15	0
	PbAsO	3.10%	13.37%	21.41%	3.52%	135	14
	PbM(Cl,SO,O)	1.77%	4.80%	1.46%	2.97%	48	1
	PbMSO4	1.77%	4.52%	2.26%	2.26%	45	1
	PbSiO4	0.18%	0.65%	0.01%	2.26%	7	Tr
	Phosphate	31.09%	52.14%	7.56%	0.72%	525	5
	SbMO	1.68%	0.61%	0.15%	7.93%	6	Tr
	Slag	9.03%	0.05%	0.01%	2.20%	Tr	Tr
	FeMSO4	3.81%	0.87%	0.69%	4.91%	9	Tr
	Cerussite	1.77%	9.93%	0.00%	3.28%	100	0
ELP-2	Anglesite	1.57%	10.12%	0.00%	2.30%	39	0
	AsFeOOH	1.12%	0.35%	2.43%	1.95%	1	1
	AsMO	1.57%	1.02%	10.33%	2.30%	4	5
	Arsenopyrite	4.26%	0.00%	59.91%	3.74%	0	29
	Cerussite	0.22%	1.72%	0.00%	0.88%	7	0
	FeOOH	12.91%	2.20%	0.81%	6.21%	9	Tr
	Galena	3.14%	30.50%	0.00%	3.23%	118	0
	PbAsO	2.24%	11.91%	16.22%	2.74%	46	8
	PbFeOOH	0.11%	0.16%	0.12%	0.62%	1	Tr
	PbM(Cl,SO,O)	2.58%	8.60%	2.22%	2.94%	33	1
	PbMSO4	2.81%	8.79%	3.74%	3.06%	34	2
	Phosphate	11.00%	22.68%	2.80%	5.79%	88	1
	Pyrite	0.79%	0.01%	0.24%	1.64%	Tr	Tr
	Slag	49.94%	0.32%	0.08%	9.26%	1	Tr
	FeMSO4	5.72%	1.61%	1.08%	4.30%	6	1
ELP-30	Arsenopyrite	1.10%	0.00%	61.62%	1.93%	0	9
	Cerussite	4.69%	39.67%	0.00%	3.92%	44	0
	CuM(SO,O)	0.10%	0.04%	0.00%	0.57%	Tr	0
	FeOOH	25.48%	4.79%	6.40%	8.07%	5	1
	Galena	0.57%	6.16%	0.00%	1.40%	7	0
	Paint	30.41%	13.55%	0.00%	8.52%	15	0
	PbAsO	0.24%	1.40%	6.89%	0.91%	2	1
	Pyrite/Chalcopyrite	0.67%	0.00%	0.82%	1.51%	Tr	Tr
	PbFeOOH	0.48%	0.78%	1.96%	1.28%	1	Tr
	PbM(Cl,SO,O)	3.21%	11.81%	10.99%	3.26%	13	2

	PbMSO4	0.14%	0.50%	0.76%	0.70%	1	Tr
	Pb	0.14%	2.70%	0.00%	0.70%	3	0
	PbSiO4	0.05%	0.24%	0.01%	0.41%	0	Tr
	Solder	0.91%	0.69%	0.02%	1.76%	1	Tr
	Phosphate	7.09%	16.14%	7.18%	4.75%	18	1
	SbMO	0.14%	0.07%	0.05%	0.70%	Tr	Tr
	Slag	20.35%	0.15%	0.13%	7.46%	Tr	Tr
	FeMSO4	4.21%	1.31%	3.16%	3.72%	1	Tr
ELP-31	AsMO	6.95%	5.74%	55.74%	6.38%	18	6
	Barite	1.74%	0.66%	0.00%	3.28%	2	0
	Cerussite	0.77%	7.53%	0.00%	2.20%	24	0
	FeOOH	41.12%	8.93%	3.16%	12.35%	29	Tr
	Galena	0.58%	7.16%	0.00%	1.90%	23	0
	MnOOH	1.93%	2.76%	0.17%	3.45%	9	Tr
	Paint	2.70%	1.39%	0.00%	4.07%	4	0
	PbAsO	3.47%	23.49%	30.62%	4.60%	75	3
	PbM(Cl,SO,O)	6.56%	27.86%	6.88%	6.21%	89	1
	Solder	2.32%	2.03%	0.02%	3.78%	6	Tr
	Phosphate	3.28%	8.62%	1.02%	4.47%	28	Tr
	Slag	18.34%	0.15%	0.04%	9.71%	Tr	Tr
	FeMSO4	10.23%	3.68%	2.35%	7.61%	12	Tr
ELP-32	Anglesite	1.85%	11.69%	0.00%	4.13%	13	0
	AsFeOOH	2.96%	0.92%	2.47%	5.19%	1	Tr
	AsMO	10.00%	6.36%	25.35%	9.18%	7	2
	Arsenopyrite	11.48%	0.00%	62.18%	9.76%	0	5
	Cerussite	5.93%	44.48%	0.00%	7.23%	48	0
	FeOOH	13.70%	2.29%	0.33%	10.53%	2	Tr
	PbAsO	2.96%	15.42%	8.26%	5.19%	16	1
	PbM(Cl,SO,O)	1.48%	4.84%	0.49%	3.70%	5	Tr
	Brass	2.96%	0.01%	0.00%	5.19%	Tr	Tr
	Phosphate	6.30%	12.73%	0.62%	7.44%	14	Tr
	Slag	36.67%	0.23%	0.02%	14.75%	Tr	Tr
	FeMSO4	3.70%	1.02%	0.27%	5.78%	1	Tr
ELP-33	AsMO	0.37%	0.23%	22.74%	1.21%	4	3
	Barite	1.10%	0.32%	0.00%	2.09%	6	0
	Cerussite	7.08%	53.15%	0.00%	5.13%	949	0
	FeOOH	42.59%	7.11%	25.25%	9.89%	127	3
	MnOOH	4.23%	4.65%	2.83%	4.03%	83	Tr
	PbM(Cl,SO,O)	0.46%	1.50%	3.72%	1.35%	27	Tr
	Solder	1.66%	1.12%	0.10%	2.55%	20	Tr
	Phosphate	14.72%	29.76%	35.19%	7.09%	531	5

	Pyrite/Chalcopyrite	1.10%	0.00%	3.17%	2.09%	Tr	Tr
	SbMO	3.22%	1.42%	2.77%	3.53%	25	Tr
	Slag	21.25%	0.13%	0.33%	8.18%	2	Tr
	FeMSO4	2.21%	0.61%	3.91%	2.94%	11	1
TM	Brass	7.14%	0.02%	0.00%	5.15%	Tr	Tr
	PbAsO	21.43%	55.45%	85.98%	8.21%	26	3
	PbM(Cl,SO,O)	21.43%	34.83%	10.23%	8.21%	16	Tr
	Solder	14.29%	4.79%	0.05%	7.00%	2	Tr
	FeMSO4	35.71%	4.91%	3.73%	9.59%	2	Tr
Z-1	Arsenopyrite	9.72%	0.00%	97.75%	8.05%	0	38
	Brass	1.54%	0.07%	0.00%	3.35%	Tr	Tr
	CuM(SO,O)	0.62%	2.32%	0.00%	2.13%	1	0
	Galena	0.62%	62.91%	0.00%	2.13%	33	0
	MnOOH	1.23%	14.53%	0.06%	3.00%	8	Tr
	Pyrite/Chalcopyrite	6.48%	0.02%	1.42%	6.69%	Tr	1
	Slag	74.69%	5.06%	0.09%	11.82%	3	Tr
	FeMSO4	5.09%	15.08%	0.69%	5.98%	8	Tr
ELP-16-Dup	Anglesite	0.49%	2.50%	0.00%	1.25%	23	0
	AsFeOOH	6.27%	1.56%	12.29%	4.34%	14	14
	AsMO	1.35%	0.69%	8.05%	2.07%	6	9
	Arsenopyrite	1.47%	0.00%	18.75%	2.16%	0	21
	FeOOH	27.27%	3.68%	1.56%	7.97%	34	2
	Galena	1.47%	11.32%	0.00%	2.16%	103	0
	MnOOH	0.61%	0.54%	0.04%	1.40%	5	0
	PbAsO	6.02%	25.27%	39.40%	4.26%	230	43
	PbFeOOH	2.33%	2.71%	2.17%	2.70%	25	2
	PbM(Cl,SO,O)	9.09%	23.96%	7.08%	5.14%	219	8
	PbMSO4	5.90%	14.62%	7.13%	4.21%	133	8
	Solder	0.61%	0.33%	0.00%	1.40%	3	0
	Phosphate	6.02%	9.82%	1.39%	4.26%	90	2
	SbMO	0.49%	0.17%	0.04%	1.25%	2	0
	Slag	18.43%	0.09%	0.03%	6.94%	1	0
	FeMSO4	12.16%	2.71%	2.07%	5.85%	25	2
ELP-30-Dup	Arsenopyrite	0.73%	0.00%	44.22%	1.66%	0	6
	Cerussite	4.67%	40.69%	0.00%	4.11%	166	0
	FeOOH	29.73%	5.77%	8.06%	8.91%	23	1
	Paint	16.67%	7.66%	0.00%	7.27%	31	0
	PbAsO	0.33%	2.01%	10.34%	1.12%	8	1
	Pyrite/Chalcopyrite	0.87%	0.00%	1.14%	1.81%	0	0
	PbFeOOH	1.13%	1.89%	4.99%	2.06%	8	1
	PbM(Cl,SO,O)	4.47%	16.95%	16.49%	4.03%	69	2
	PbSiO4	0.33%	1.70%	0.07%	1.12%	7	0

Solder	0.33%	0.26%	0.01%	1.12%	1	0
Phosphate	8.93%	20.99%	9.76%	5.56%	85	1
Slag	25.93%	0.19%	0.18%	8.55%	1	0
FeMSO4	5.87%	1.88%	4.74%	4.58%	8	1

*E-95%= Estamated counting error at 95% confidence, Mossiman, 1965.

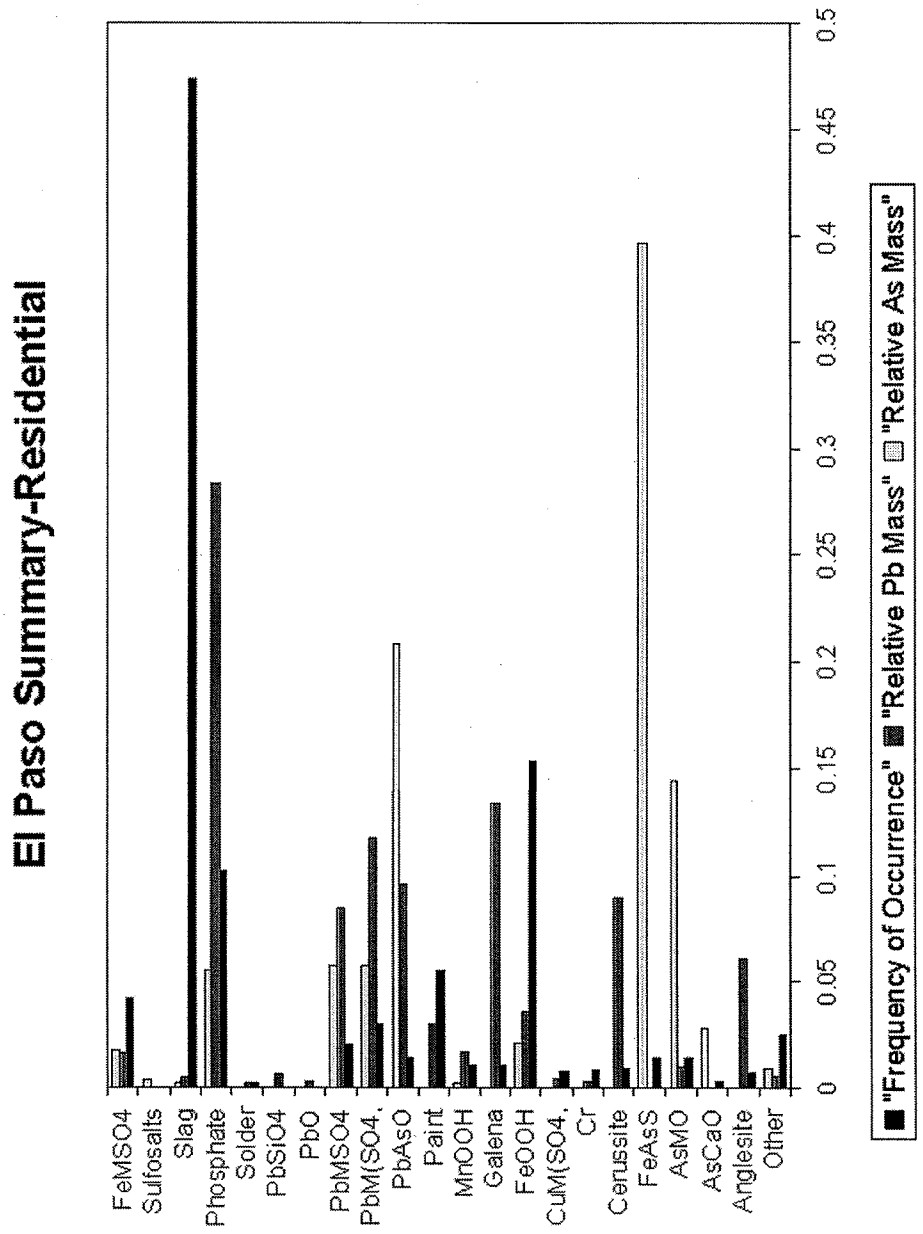
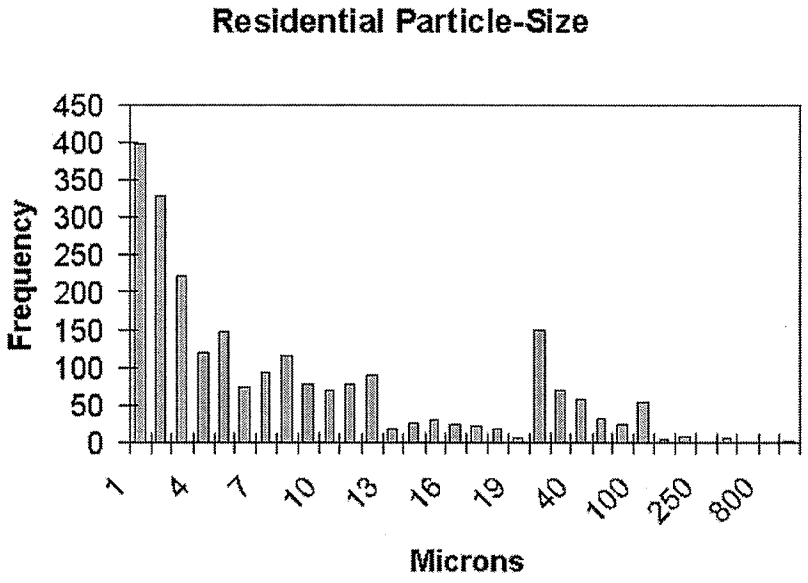

El Paso Summary-Residential
FeMSO4
Sulfosalts
Slag
Phosphate
Solder
PbSiO4
PbO
PbMSO4
PbM(SO4,
PbAsO
Paint
MnOOH
Galena
FeOOH
CuM(SO4,
Cr
Cerussite
FeAsS
AsMO
AsCaO
Anglesite
Other
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
"Frequency of Occurrence"
"Relative Pb Mass"
"Relative As Mass"

Fig 4

Fig5


Residential Particle-Size
Frequency
450
400
350
300
250
200
150
100
50
0
1
4
7
10
13
16
19
40
100
250
800
Microns

Statistical Study–Correlation Analysis

A matrix was constructed using twenty-six variables and 26 cases (soil samples) and twenty-six variables and 6 cases (plant samples) to conduct a correlation analysis using *STATISTICA*. The variables included data from the El Paso speciation study (Min_{Pb}), and bulk metals concentrations. Based on these data a correlation matrix was computed for each group.

Correlations within the residential samples can be used for apportionment calculations. These correlations are often valuable in assigning source(s) to "non-specific" phases and phases that can be common to multiple sources. However, one must remember that a correlation does not necessarily indicate an association! Other statistical techniques can be applied to the data and may offer further insight. The most significant correlations between variable pairs have been marked in **bold** in Tables 5- 6. Many of these correlations support the categories established later in Chapter 6.

For plant soils, correlation coefficients suggest; 1) bulk lead and arsenic concentrations at the plant are dominated by emission products and 2) all of the pyrometalurgical phases (except slag) proposed in Chapter 6 show a strong correlation and 3) all concentrate phases (except anglesite) proposed in Chapter 6 show a strong correlation.

For community soils a number of observations that one can make from the data, which may be important to this study, are; 1) that bulk lead and arsenic do not correlate highly ($r > 0.80$, $p < 0.05$) with any particular phase 2) bulk cadmium however does correlate well with all emission products 3) concentrate phases, other than pyrite and sulfosalts are poorly correlated to other factors 4) the total lack of a correlation between paint and any other phase, particularly anglesite,

cerussite or lead oxide, or bulk metal concentration 5) "solder" may be miss-identified as an anthropogenic phase, and may be a by product from the facility and 6) most (9 out of 12) of the proposed pyrometalurgical phases show good inter-phase correlation.

Table 5. Correlation matrix of Factor Analysis

TABLE 5. Plant speciation correlations.

Marked correlations are significant at p < .05000

	Anglesite	AsFeOOH	AsMO	AsMSO4	BiMO	Cerussite	CrMO	Cu	CuMO	CuMSO4	FeOOH	Galena	MnOOH	PbAsO	PbVAsO	PbFeOOH	PbMO	PbMSO4	PbO	PbSiO4	Phos	Slag	SS	FeMSO4	Bulk Pb	Bulk As
Anglesite	1.00	0.10	0.04	0.67	-0.39	-0.41	0.67	-0.33	-0.41	0.67	0.16	-0.46	0.26	0.12	0.67	0.23	-0.10	0.67	-0.38	-0.11	-0.47	-0.25	-0.34	0.23	0.65	0.60
AsFeOOH	0.10	1.00	**0.84**	-0.24	-0.24	-0.23	-0.24	-0.27	-0.21	-0.24	**0.88**	-0.37	**0.89**	**0.91**	-0.24	**0.87**	0.61	-0.22	0.15	0.59	0.32	-0.31	0.16	**0.90**	-0.19	-0.27
AsMO	0.04	**0.84**	1.00	-0.30	-0.32	-0.30	-0.30	-0.33	-0.28	-0.30	**0.96**	-0.42	**0.85**	**0.98**	-0.30	**0.90**	0.61	-0.29	0.22	0.53	0.03	-0.38	-0.04	**0.89**	-0.26	-0.35
AsMSO4	0.67	-0.24	-0.30	1.00	-0.13	-0.17	**1.00**	-0.06	-0.19	**1.00**	-0.24	-0.27	-0.17	-0.23	**1.00**	-0.19	-0.31	**1.00**	-0.42	-0.29	-0.27	-0.18	-0.17	-0.20	**0.98**	**0.98**
BiMO	-0.39	-0.24	-0.32	-0.13	1.00	**1.00**	-0.13	**1.00**	**1.00**	-0.13	-0.26	**0.95**	-0.19	-0.24	-0.13	-0.22	0.47	-0.08	**0.81**	0.55	0.32	-0.26	**0.86**	-0.22	0.04	0.07
Cerussite	-0.41	-0.23	-0.30	-0.17	**1.00**	1.00	-0.17	**0.99**	**1.00**	-0.17	-0.24	**0.96**	-0.17	-0.23	-0.17	-0.20	0.49	-0.12	**0.83**	0.57	0.30	-0.24	**0.86**	-0.20	0.00	0.03
CrMO	0.67	-0.24	-0.30	**1.00**	-0.13	-0.17	1.00	-0.06	-0.19	**1.00**	-0.24	-0.27	-0.17	-0.23	**1.00**	-0.19	-0.31	**1.00**	-0.42	-0.29	-0.27	-0.18	-0.17	-0.20	**0.98**	**0.98**
Cu	-0.33	-0.27	-0.33	-0.06	**1.00**	**0.99**	-0.06	1.00	**0.99**	-0.06	-0.27	**0.95**	-0.19	-0.25	-0.06	-0.22	0.46	-0.01	**0.80**	0.55	0.26	-0.26	**0.86**	-0.22	0.11	0.14
CuMO	-0.41	-0.21	-0.28	-0.19	**1.00**	**1.00**	-0.19	**0.99**	1.00	-0.19	-0.22	**0.96**	-0.15	-0.21	-0.19	-0.18	0.50	-0.14	**0.84**	0.59	0.31	-0.24	**0.87**	-0.18	-0.02	0.01
CuMSO4	0.67	-0.24	-0.30	**1.00**	-0.13	-0.17	**1.00**	-0.06	-0.19	1.00	-0.24	-0.27	-0.17	-0.23	**1.00**	-0.19	-0.31	**1.00**	-0.42	-0.29	-0.27	-0.18	-0.17	-0.20	**0.98**	**0.98**
FeOOH	0.16	**0.88**	**0.96**	-0.24	-0.26	-0.24	-0.24	-0.27	-0.22	-0.24	1.00	-0.36	**0.95**	**0.99**	-0.24	**0.99**	0.71	-0.22	0.29	0.64	-0.07	-0.31	0.09	**0.98**	-0.17	-0.27
Galena	-0.46	-0.37	-0.42	-0.27	**0.95**	**0.96**	-0.27	**0.95**	**0.96**	-0.27	-0.36	1.00	-0.27	-0.37	-0.27	-0.30	0.38	-0.23	0.79	0.45	0.17	-0.01	**0.81**	-0.30	-0.11	-0.08
MnOOH	0.26	**0.89**	**0.85**	-0.17	-0.19	-0.17	-0.17	-0.19	-0.15	-0.17	**0.95**	-0.27	1.00	**0.92**	-0.17	**0.99**	0.77	-0.14	0.32	0.71	-0.09	-0.21	0.23	**1.00**	-0.08	-0.18
PbAsO	0.12	**0.91**	**0.98**	-0.23	-0.24	-0.23	-0.23	-0.25	-0.21	-0.23	**0.99**	-0.37	**0.92**	1.00	-0.23	**0.95**	0.70	-0.21	0.27	0.63	0.08	-0.41	0.09	**0.95**	-0.17	-0.26
PbVAsO	0.67	-0.24	-0.30	**1.00**	-0.13	-0.17	**1.00**	-0.06	-0.19	**1.00**	-0.24	-0.27	-0.17	-0.23	1.00	-0.19	-0.31	**1.00**	-0.42	-0.29	-0.27	-0.18	-0.17	-0.20	**0.98**	**0.98**
PbFeOOH	0.23	**0.87**	**0.90**	-0.19	-0.22	-0.20	-0.19	-0.22	-0.18	-0.19	**0.99**	-0.30	**0.99**	**0.95**	-0.19	1.00	0.76	-0.17	0.33	0.69	-0.13	-0.25	0.17	**1.00**	-0.11	-0.22
PbMO	-0.10	0.61	0.61	-0.31	0.47	0.49	-0.31	0.46	0.50	-0.31	0.71	0.38	0.77	0.70	-0.31	0.76	1.00	-0.25	**0.85**	**0.99**	0.08	-0.35	0.73	0.75	-0.12	-0.19
PbMSO4	0.67	-0.22	-0.29	**1.00**	-0.08	-0.12	**1.00**	-0.01	-0.14	**1.00**	-0.22	-0.23	-0.14	-0.21	**1.00**	-0.17	-0.25	1.00	-0.37	-0.23	-0.26	-0.21	-0.12	-0.17	**0.99**	**0.99**
PbO	-0.38	0.15	0.22	-0.42	**0.81**	**0.83**	-0.42	**0.80**	**0.84**	-0.42	0.29	0.79	0.32	0.27	-0.42	0.33	**0.85**	-0.37	1.00	**0.86**	0.11	-0.26	**0.85**	0.31	-0.23	-0.25
PbSiO4	-0.11	0.59	0.53	-0.29	0.55	0.57	-0.29	0.55	0.59	-0.29	0.64	0.45	0.71	0.63	-0.29	0.69	**0.99**	-0.23	**0.86**	1.00	0.18	-0.38	**0.80**	0.69	-0.09	-0.16
Phos	-0.47	0.32	0.03	-0.27	0.32	0.30	-0.27	0.26	0.31	-0.27	-0.07	0.17	-0.09	0.08	-0.27	-0.13	0.08	-0.26	0.11	0.18	1.00	-0.37	0.31	-0.08	-0.25	-0.22
Slag	-0.25	-0.31	-0.38	-0.18	-0.26	-0.24	-0.18	-0.26	-0.24	-0.18	-0.31	-0.01	-0.21	-0.41	-0.18	-0.25	-0.35	-0.21	-0.26	-0.38	-0.37	1.00	-0.12	-0.24	-0.26	-0.24
SS	-0.34	0.16	-0.04	-0.17	**0.86**	**0.86**	-0.17	**0.86**	**0.87**	-0.17	0.09	**0.81**	0.23	0.09	-0.17	0.17	0.73	-0.12	**0.85**	**0.80**	0.31	-0.12	1.00	0.19	0.02	0.01
FeMSO4	0.23	**0.90**	**0.89**	-0.20	-0.22	-0.20	-0.20	-0.22	-0.18	-0.20	**0.98**	-0.30	**1.00**	**0.95**	-0.20	**1.00**	0.75	-0.17	0.31	0.69	-0.08	-0.24	0.19	1.00	-0.11	-0.22
Bulk Pb	0.65	-0.19	-0.26	**0.98**	0.04	0.00	**0.98**	0.11	-0.02	**0.98**	-0.17	-0.11	-0.08	-0.17	**0.98**	-0.11	-0.12	**0.99**	-0.23	-0.09	-0.25	-0.26	0.02	-0.11	1.00	**0.99**
Bulk As	0.60	-0.27	-0.35	**0.98**	0.07	0.03	**0.98**	0.14	0.01	**0.98**	-0.27	-0.08	-0.18	-0.26	**0.98**	-0.22	-0.19	**0.99**	-0.25	-0.16	-0.22	-0.24	0.01	-0.22	**0.99**	1.00

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Table 6

TABLE 6. Correlation matrix for Residential Soils

Marked correlations are significant at p < .05000

	Anglesite	AsFeOOH	AsMO	Arsenopyrite	Cerussite	CuMO	FeOOH	Galena	MnOOH	Paint	PbAsO	PbFeOOH	PbMO	PbMSO4	PbO	PbSiO4	Solder	Phosphate	Pyrite	SbMO	Slag	Sulfosalt	FeMSO4	Bulk Pb	Bulk As	Bulk Cd
Anglesite	1.00	0.26	0.29	-0.01	0.12	0.32	0.04	0.31	0.02	0.23	-0.05	0.07	-0.05	0.01	0.19	0.16	0.27	-0.15	0.26	0.25	0.21	0.25	0.17	-0.03	0.02	0.37
AsFeOOH	0.26	1.00	**0.90**	0.42	0.67	**0.92**	0.60	0.06	0.44	0.42	0.12	0.67	0.12	0.06	**0.89**	**0.81**	**0.98**	-0.17	**0.99**	**0.99**	**0.92**	**0.98**	**0.88**	-0.35	0.25	**0.91**
AsMO	0.29	**0.90**	1.00	0.30	0.73	**0.97**	0.72	0.09	0.45	0.49	0.19	0.57	0.20	-0.02	**0.80**	0.72	**0.94**	0.05	**0.91**	**0.91**	**0.84**	**0.91**	**0.82**	-0.14	0.20	**0.93**
Arsenopyrite	-0.01	0.42	0.30	1.00	0.21	0.35	0.07	0.16	0.07	-0.01	-0.28	0.48	-0.20	0.01	0.44	0.29	0.41	-0.38	0.44	0.44	0.37	0.44	0.49	-0.53	0.77	0.24
Cerussite	0.12	0.67	0.73	0.21	1.00	0.62	0.50	0.12	0.30	0.28	0.14	0.35	-0.01	-0.02	0.60	0.58	0.68	0.15	0.69	0.72	0.63	0.68	0.56	-0.08	0.20	0.69
CuMO	0.32	**0.92**	**0.97**	0.35	0.62	1.00	0.66	0.10	0.40	0.49	0.07	0.59	0.13	0.06	**0.84**	0.75	**0.96**	-0.06	**0.93**	**0.92**	**0.89**	**0.93**	**0.82**	-0.24	0.19	**0.92**
FeOOH	0.04	0.60	0.72	0.07	0.50	0.66	1.00	-0.26	0.46	0.32	0.36	0.44	0.53	-0.11	0.56	0.44	0.67	0.45	0.61	0.62	0.52	0.62	0.60	0.22	0.19	0.72
Galena	0.31	0.06	0.09	0.16	0.12	0.10	-0.26	1.00	-0.27	-0.09	-0.06	0.09	-0.17	0.08	0.06	-0.03	0.03	-0.20	0.04	0.06	0.04	0.02	0.14	0.05	0.13	0.14
MnOOH	0.02	0.44	0.45	0.07	0.30	0.40	0.46	-0.27	1.00	0.11	0.44	0.26	0.44	-0.06	0.37	0.38	0.46	0.13	0.46	0.44	0.41	0.52	0.56	0.07	0.11	0.44
Paint	0.23	0.42	0.49	-0.01	0.28	0.49	0.32	-0.09	0.11	1.00	-0.06	0.38	0.13	-0.12	0.38	0.30	0.46	-0.11	0.44	0.43	0.38	0.44	0.36	-0.05	-0.13	0.45
PbAsO	-0.05	0.12	0.19	-0.28	0.14	0.07	0.36	-0.06	0.44	-0.06	1.00	0.19	0.55	-0.05	0.11	0.30	0.08	0.45	0.05	0.07	-0.01	0.07	0.20	0.60	0.09	0.25
PbFeOOH	0.07	0.67	0.57	0.48	0.35	0.59	0.44	0.09	0.26	0.38	0.19	1.00	0.31	0.31	0.66	0.50	0.65	-0.19	0.66	0.66	0.69	0.66	0.78	0.01	0.55	0.68
PbMO	-0.05	0.12	0.20	-0.20	-0.01	0.13	0.53	-0.17	0.44	0.13	0.55	0.31	1.00	0.00	0.01	-0.07	0.08	0.22	0.05	0.07	0.01	0.10	0.37	0.56	0.16	0.28
PbMSO4	0.01	0.06	-0.02	0.01	-0.02	0.06	-0.11	0.08	-0.06	-0.12	-0.05	0.31	0.00	1.00	0.20	-0.01	0.03	-0.32	0.05	0.06	0.35	0.06	0.10	0.14	0.29	0.10
PbO	0.19	**0.89**	**0.80**	0.44	0.60	**0.84**	0.56	0.06	0.37	0.38	0.11	0.66	0.01	0.20	1.00	0.73	**0.90**	-0.23	**0.91**	**0.90**	**0.87**	**0.90**	0.76	-0.36	0.27	**0.81**
PbSiO4	0.16	**0.81**	0.72	0.29	0.58	0.75	0.44	-0.03	0.38	0.30	0.30	0.50	-0.07	-0.01	0.73	1.00	**0.81**	0.12	**0.82**	**0.83**	0.77	**0.81**	0.68	-0.16	0.17	0.79
Solder	0.27	**0.98**	**0.94**	0.41	0.68	**0.96**	0.67	0.03	0.46	0.46	0.08	0.65	0.08	0.03	**0.90**	**0.81**	1.00	-0.07	**0.99**	**0.99**	**0.93**	**0.99**	**0.86**	-0.31	0.22	**0.93**
Phosphate	-0.15	-0.17	0.05	-0.38	0.15	-0.06	0.45	-0.20	0.13	-0.11	0.45	-0.19	0.22	-0.32	-0.23	0.12	-0.07	1.00	-0.15	-0.12	-0.19	-0.14	-0.13	0.66	-0.09	0.09
Pyrite	0.26	**0.99**	**0.91**	0.44	0.69	**0.93**	0.61	0.04	0.46	0.44	0.05	0.66	0.05	0.05	**0.91**	**0.82**	**0.99**	-0.15	**1.00**	**1.00**	**0.94**	**1.00**	**0.87**	-0.36	0.24	**0.91**
SbMO	0.25	**0.99**	**0.91**	0.44	0.72	**0.92**	0.62	0.06	0.44	0.43	0.07	0.66	0.07	0.06	**0.90**	**0.83**	**0.99**	-0.12	1.00	1.00	**0.93**	**0.99**	**0.88**	-0.34	0.26	**0.92**
Slag	0.21	**0.92**	**0.84**	0.37	0.63	**0.89**	0.52	0.04	0.41	0.38	-0.01	0.69	0.01	0.35	**0.87**	0.77	**0.93**	-0.19	**0.94**	**0.93**	1.00	**0.94**	**0.81**	-0.29	0.26	**0.88**
Sulfo	0.25	**0.98**	**0.91**	0.44	0.68	**0.93**	0.62	0.02	0.52	0.44	0.07	0.66	0.10	0.06	**0.90**	**0.81**	**0.99**	-0.14	**1.00**	**0.99**	**0.94**	1.00	**0.89**	-0.34	0.25	**0.92**

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salt																									
FeM	0.17	**0.88**	**0.82**	0.49	0.56	**0.82**	0.60	0.14	0.56	0.36	0.20	0.78	0.37	0.10	0.76	0.68	**0.86**	-0.13	**0.87**	**0.88**	**0.81**	**0.89**	1.00	-0.12	0.43	**0.87**
SO4																									
Bulk	-0.03	-0.35	-0.14	-0.53	-0.08	-0.24	0.22	0.05	0.07	-0.05	0.60	0.01	0.56	0.14	-0.36	-0.16	-0.31	0.66	-0.36	-0.34	-0.29	-0.34	-0.12	1.00	0.03	0.01
Pb																									
Bulk	0.02	0.25	0.20	0.77	0.20	0.19	0.19	0.13	0.11	-0.13	0.09	0.55	0.16	0.29	0.27	0.17	0.22	-0.09	0.24	0.26	0.26	0.25	0.43	0.03	1.00	0.25
As																									
Bulk	0.37	**0.91**	**0.93**	0.24	0.69	**0.92**	0.72	0.14	0.44	0.45	0.25	0.68	0.28	0.10	**0.81**	0.79	**0.93**	0.09	**0.91**	**0.92**	**0.88**	**0.92**	**0.87**	0.01	0.25	1.00
Cd																									

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5.0 LEAD ISOTOPIC CHARACTERIZATION

As anticipated, the community soils in the El Paso area have a considerable fraction of their bulk lead associated with the soil forming phases (phosphates, MnOOH and FeOOH). These phase are "non-source specific" in there lead concentration, and represent a mixture of all soluble lead forms historically associated with the soil. Therefore, a new methodology, using ICP/MS/LA to determine lead isotopic values for a single soil particle was conducted in order to provide insight into lead sources for these important and often abundant lead forms.

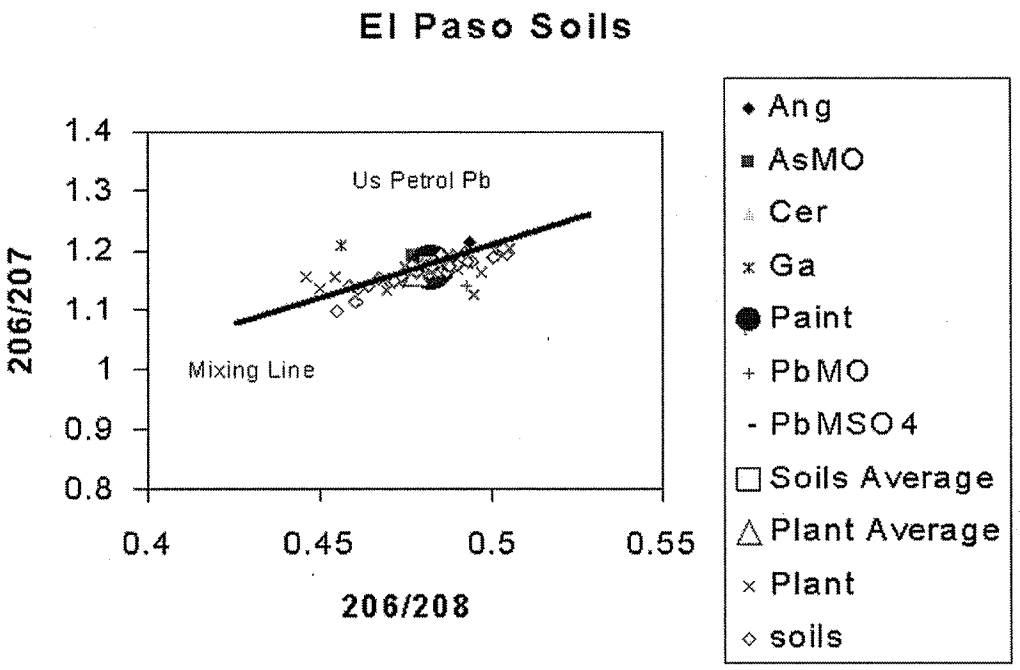
Both bulk and single particle isotopic lead values were determined on a VARIAN Ultramass inductive coupled plasma mass spectrometer (ICPMS) equipped with a CETAC LS200 laser ablation unit. Bulk samples were prepared following USEPA 3050/6010 while single particles were analyzed from identified lead particles in EMPA pucks. A complete SOP for ICP/MS/LA is provided in the Appendix. Both sample sets were standardized using NIST 982 and/or 3128. The isotopes of lead Pb^{207}, Pb^{206}, and Pb^{208} are produced by the radioactive decay of U^{235}, U^{238} and Th^{232} respectively, while Pb^{204} has no radiogenic source. Variations are a function of the initial uranium and thorium concentrations and age of the ore.

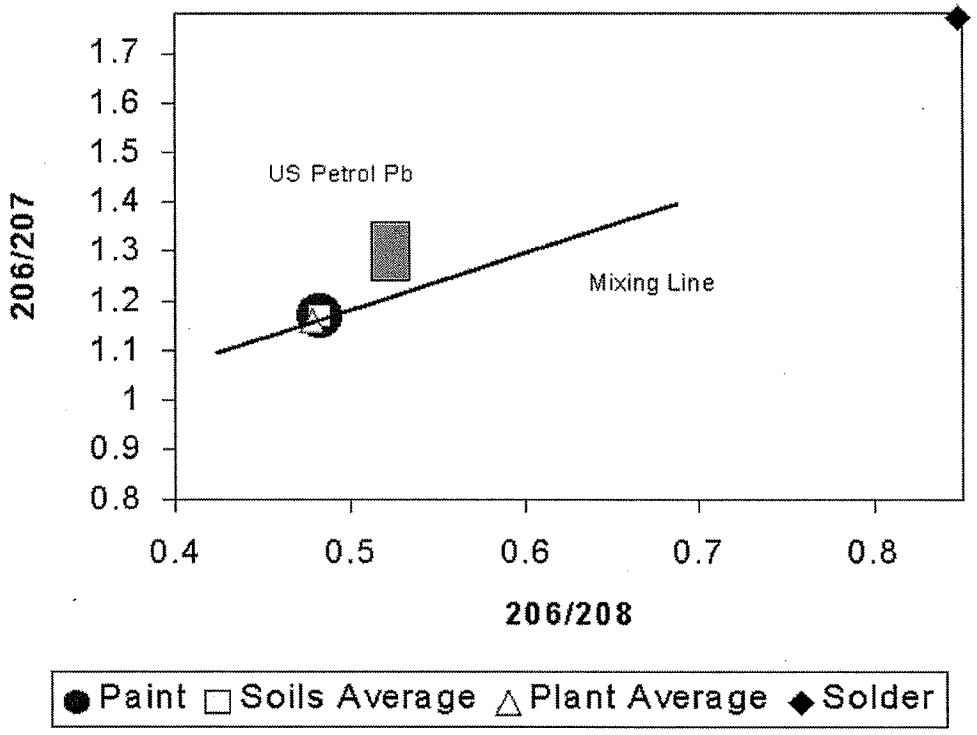
Lead isotopic compositions have been previously used in apportionment studies with some limited success (Hurst et.al., 1996, Gulson et al., 1995, 1996, Robinowitz and Wetherill, 1972, and Sturges and Barrie, 1987, 1989). The major difficulty with these studies was in the sole use of bulk sample analyses. This isotopic signature represents a mixture of all lead sources, therefore apportionment is complicated when more than two sources are involved. With the improvements made in quadrupole ICP/MS systems and the advancements in laser technology, we can now combine EMPA studies (identification of lead-bearing phases) with single particle isotopic lead analysis.

Isotopic results on site samples along with those from the NIST 928 standard are presented in Figure 8. The absolute value and variations about the NIST standard, although not equivalent to a magnetic sector mass spectrometer, provides a good estimate of the precision (2%) and accuracy (3%) at a 95% confidence level for quadrupole ICP/MS/LA.

The three most abundant isotopes of lead Pb^{208}, Pb^{206} and Pb^{207} (54%, 24%, and 22%, respectively) are the most useful for source characterization. Figure 8, a plot of $Pb^{206/207}$ vs $Pb^{206/208}$, illustrates some of the most important characteristics of the data set. It is clear that the ASARCO plant soils have a very wide range in isotopic composition that is likely the result of its more extensive operational history and numerous lead-ore sources (Mexico, New Mexico, Arizonia, and Colorado). Preliminary review of the data would support multiple primary lead sources for the plant. Data from the community soils was much more difficult to obtain. Single-phase laser analyses were limited to a few phases, paint, and solder primarily do to the size limitations in finding a single particle of lead using the low power microscope on the laser. Therefore, bulk isotopic lead analyses were included for characterization. The bulk isotopic lead samples however are represented by a rather broad distribution, overlapping the ASARCO population . Figure 8B is a simplified $Pb^{206/208}$ vs $Pb^{206/207}$ plot, using only average values for all potential sources and soil. In this plot it becomes more apparent that the community soils are isotopically similar to the ASARCO facility soils and that a contribution from lead paint can not be ruled out isotopically, however, gasoline and solder are not significant contributors to their isotopic character.

Figure 8


El Paso Soils
206/207
206/208
Us Petrol Pb
Mixing Line
1.4
1.3
1.2
1.1
1
0.9
0.8
0.4
0.45
0.5
0.55
Ang
AsMO
Cer
Ga
Paint
PbMO
PbMSO4
Soils Average
Plant Average
Plant
soils


206/207
206/208
US Petrol Pb
Mixing Line
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.4
0.5
0.6
0.7
0.8
Paint
Soils Average
Plant Average
Solder

6.0 APPORTIONMENT

Based on the results from the arsenic speciation study an attempt to apportion the total soil lead and arsenic to most probable sources was made using the $Min_{Pb\text{-}As}$ values (Tables 7 and 8). Thus four specific categories for the apportionment were made: pyrometallurgical , concentrate, non-specific soil-forming, and anthropogenic. Criteria for each of these categories were as follows:

Pyrometallurgical : PbAsO, AsFeOOH, PbMO, AsMO, PbFeOOH, $PbMSO_4$

Concentrate: Galena, anglesite, sulfosalts, arsenopyrite, and pyrite

Soil-Forming : Fe oxide, Mn oxide, phosphate, and clays

Anthropogenic: Paint, brass, AsCaO, and solder

Pyrometallurgical and concentrate species were chosen based on data from site-specific, ASARCO plant samples, metallurgical literature (Fergusson, 1990), and previous studies (Drexler, 1995,1997; Thorton 1995). The soil-forming phases are most likely the result of solublized lead and/or arsenic, released from the other two populations that are now sequestered (by sorption) in common, soil-forming mineral phases. Since at least some of the bulk metal found in this category may have come from pyrometallurgical processes or concentrate

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alterations, a percentage of the "non-source specific" category could be assigned to these sources. Site specific examples, Photos 12-15, clearly illustrate that this argument is valid, showing primary smelter and concentrate phases altering to phosphates, clays, and manganese oxides that contain arsenic and lead.

Possible residential anthropogenic forms of lead/arsenic include: brass, solder, gasoline, pesticides, glass, and paint. Anthropogenic species were chosen based on data from literature (Fergusson, 1990), and previous studies (Drexler, 1995,1997; Thorton 1995). Lead paint is characteristically associated with following forms of lead: lead carbonate, lead sulfate, lead oxide, and lead chromate. The presence of lead paint in approximately 30% of the residential homes near the ASARCO facility was noted by Landrigan et al., 1975. Since both $PbSO_4$ and $PbCO_3$ are both common lead ores (concentrates) and paint pigments one must define a rational for its apportionment. The author apportioned all of the $PbSO_4$ to "concentrate", since the ASARCO facility contained a significant quantity of anglesite and it is the least common white-lead pigment, while all of the $PbCO_3$ was apportioned to "anthropogenic", since little cerussite was found at the facility and it is the most common white-lead pigment. In general, this rational would only have had a significant impact on two residential samples (ELP-6 and ELP-33). One under estimating facility apportionment and the other paint apportionment, thus not impacting the overall apportionment. Pigments of arsenic are rare and not considered a likely source. Pesticides would typically contain lead, calcium, or sodium arsenate. Gasoline as a significant source is unlikely because of the historical rural location of the plant and even though today, major roadways are within the area, lead contamination from automobile emissions or spills is generally limited to a few hundred feet of a roadway. This conclusion is also supported by both the isotopic data (Chapter 5) and the study of Landrigan et al., 1975.

Results of the apportionment are summarized in Tables 7 and 8. The apportionment calculation indicates that on average a minimum of 53% of the bulk lead in residential soils can be attributed to the ASARCO facility either as a result of stack emissions or fugitive dust from concentrate piles. This value would increase to 64% if only a third of the non-specific lead was apportioned to ASARCO as justified previously. Virtually all, 85%, of the arsenic is most likely from the ASARCO facility.

Table 7

TABLE 7. Lead Apportionment Distribution for Residential Soils

		ELP-9	ELP-8	ELP-7	ELP-6	ELP-5	ELP-4	ELP-3	ELP-22	ELP-21	ELP-20	ELP-19	ELP-18	ELP-17	ELP-16	ELP-15	ELP-14	ELP-13	ELP-12	ELP-11	ELP-10	ELP-1	ELP-2	ELP-30	ELP-31	ELP-32	ELP-33
		849	121	165	838	388	932	217	381	818	1162	528	604	948	912	803	1116	912	376	1143	854	1007	388	407	316	108	1785
Pyrometalurgical																											
	PbAsO	39	0	0	43	44	204	0	9	158	101	0	125	76	213	99	221	6	3	154	105	135	46	2	75	16	0
	Cr	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0	0	0	0	0	0	0	0	0	0	0	0
	CuM(SO,O)	0	0	0	5	2	0	0	0	0	38	0	2	0	1	0	1	8	0	1	2	0	0	0	0	0	0
	AsFeOOH	4	1	0	0	3	0	1	1	4	0	0	0	0	15	2	1	0	1	0	1	0	1	0	0	1	0
	AsMO	0	0	2	3	4	0	0	0	3	40	0	0	2	10	0	8	1	1	11	8	20	4	0	18	7	4
	PbAsVO	0	0	0	0	0	0	0	0	0	0	0	0	129	30	0	0	0	0	0	0	0	0	0	0	0	0
	PbM(Cl,SO,O)	219	1	0	37	15	6	0	0	47	157	42	46	132	218	49	287	42	2	104	228	48	33	13	89	5	27
	PbMSO4	114	2	57	104	0	0	6	0	121	20	67	286	21	110	28	59	430	6	0	25	45	34	1	0	0	0
	PbO	0	0	0	0	0	0	0	0	0	0	0	43	0	0	17	0	0	0	0	0	0	0	0	0	0	0
	PbSiO4	0	0	0	0	0	63	0	0	27	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
	SbMO	4	0	0	0	0	0	0	2	6	0	3	0	2	3	1	0	0	0	0	0	6	0	0	0	0	25
	Slag	3	0	0	1	0	3	2	2	0	0	0	7	0	1	0	0	45	0	0	1	0	1	0	0	0	2
	FeMSO4	20	2	11	9	1	3	8	6	23	15	35	3	9	22	18	36	18	0	7	28	9	6	1	12	1	11
	PbFeOOH	0	0	0	8	0	11	0	0	9	0	52	31	16	42	25	12	55	0	19	74	0	1	0	0	0	0
Total Pyrometalurgical		402	5	70	210	70	289	17	21	399	371	199	544	446	666	239	625	605	12	295	472	270	127	17	194	30	69
% of total Pb		47%	4%	42%	25%	18%	31%	8%	5%	49%	32%	38%	90%	47%	73%	30%	56%	66%	3%	26%	55%	27%	33%	4%	61%	28%	4%
Concentrate	Arsenopyrite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Barite	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	6
	Galena	27	105	6	195	102	0	48	0	174	148	173	10	8	111	337	0	152	31	0	29	141	118	7	23	0	0
	Anglesite	0	10	8	279	39	0	0	0	14	57	0	0	0	37	0	0	0	13	32	0	0	39	0	0	13	0
	Pyrite	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sulfosalts	2	0	0	0	0	0	1	0	0	0	2	0	0	0	0	8	1	1	0	1	0	0	0	0	0	0
Total Concentrate		29	115	14	474	141	0	50	0	188	205	177	11	9	148	337	8	153	44	32	30	141	158	7	25	13	6
% of total Pb		3%	95%	8%	57%	36%	0%	23%	0%	23%	18%	33%	2%	1%	16%	42%	1%	17%	12%	3%	3%	14%	41%	2%	8%	12%	0%
	AsCaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Anthropogenic	Cerusite	0	0	0	0	6	0	0	0	0	0	0	0	13	0	0	0	0	230	0	0	100	7	44	24	48	949
	Paint	17	0	0	34	0	0	0	0	13	53	0	12	0	0	0	0	0	47	25	93	15	0	15	4	0	0
	Solder	0	0	0	0	0	0	0	0	0	9	0	0	1	0	0	0	0	0	10	0	0	0	1	6	0	20
Total Anthropogenic		17	0	0	34	6	0	0	0	13	62	0	12	14	0	0	0	0	277	35	93	120	7	60	34	48	969
% of total Pb		2%	0%	0%	4%	1%	0%	0%	0%	2%	5%	0%	2%	1%	0%	0%	0%	0%	74%	3%	11%	12%	2%	15%	11%	44%	54%
Non-Specific	Clay	6	0	0	0	0	6	0	0	0	0	0	0	0	0	0	4	0	0	4	0	0	0	0	0	0	0
	FeOOH	57	1	0	8	22	17	30	34	17	60	12	35	53	27	14	40	9	3	70	45	38	9	5	29	2	127

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MnOO H	0	0	0	0	0	20	13	0	0	0	0	0	0	5	0	168	6	7	46	0	13	0	0	9	0	83					
Organic	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
Phosphate	339	0	82	112	150	597	97	313	201	464	140	2	425	66	212	270	138	33	661	215	525	88	18	28	14	535					
Total Non-Specific	401	1	82	120	172	643	150	360	219	524	152	37	478	97	226	483	153	43	781	260	576	97	23	66	16	745					
% of total Pb	47%	1%	50%	14%	44%	69%	69%	95%	27%	45%	29%	6%	50%	11%	28%	43%	17%	11%	68%	30%	57%	25%	6%	21%	15%	42%					
Total ASARCO Contribution	51%	99%	50%	82%	54%	31%	31%	5%	72%	50%	71%	92%	48%	89%	72%	57%	83%	15%	29%	59%	41%	73%	6%	69%	40%	4%	53%				
Asarco + 33% of non-specific	66%	99%	67%	86%	69%	54%	54%	37%	81%	64%	81%	94%	65%	93%	81%	71%	89%	19%	51%	69%	60%	82%	8%	76%	45%	18%	64%				

table 8

TABLE 8. Arsenic Apportionment Distribution for Residential Soils

		ELP-9	ELP-8	ELP-7	ELP-6	ELP-5	ELP-4	ELP-3	ELP-22	ELP-21	ELP-20	ELP-19	ELP-18	ELP-17	ELP-16	ELP-15	ELP-14	ELP-13	ELP-12	ELP-11	ELP-10	ELP-1	ELP-2	ELP-30	ELP-31	ELP-32	ELP-33
		67	57	16	58	40	51	47	32	41	44	192	66	45	110	31	69	65	14	62	56	65	48	14	12	8	13
Pyrometalurgical																											
	AsFeOOH	6	1	0	0	3	0	0	1	2	0	0	0	0	14	2	1	0	2	0	1	0	1	0	0	0	0
	AsMO	0	0	2	9	6	0	0	0	2	26	0	0	3	14	0	9	2	3	15	10	15	5	0	6	2	3
	SbMO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PbAsO	13	0	0	20	8	38	0	2	15	9	0	9	18	40	18	34	2	2	27	18	14	8	1	3	1	0
	PbAsVO	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	PbFeOOH	0	0	0	2	0	1	0	0	0	0	6	1	2	4	2	1	8	0	2	6	0	0	0	0	0	0
	PbM(Cl,SO,O)	14	0	0	3	1	0	0	0	1	3	2	1	6	8	2	8	2	0	3	7	1	1	2	1	0	0
	Slag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	FeMSO4	3	0	1	2	0	0	0	1	1	1	4	0	1	2	2	3	3	0	1	2	0	1	0	0	0	1
Total Pyrometalurgical		37	1	2	37	17	39	0	4	21	39	12	11	31	82	25	56	19	8	48	45	31	16	3	10	3	4
% of total As		55%	2%	15%	64%	42%	77%	1%	13%	52%	89%	6%	17%	69%	74%	82%	82%	30%	58%	77%	81%	47%	32%	21%	83%	38%	31%
Concentrate	PbMSO4	12	0	2	15	0	0	0	0	4	1	5	7	2	6	2	3	40	2	0	1	1	2	0	0	0	0
	Arsenopyrite	0	54	10	0	20	0	45	19	14	0	163	46	0	19	0	0	0	0	0	3	0	29	9	0	5	0
	Pyrite	0	1	0	0	0	0	1	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sulfosalts	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0
Total Concentrate		14	56	13	15	20	0	46	19	17	1	176	54	2	26	2	6	41	3	0	5	1	31	9	0	5	0
% of total As		21%	98%	79%	26%	49%	0%	97%	61%	42%	3%	92%	82%	3%	23%	6%	8%	63%	18%	0%	10%	2%	64%	64%	0%	63%	0%
Anthropogenic																											
	AsCaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0
Total Anthropogenic		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0
% of total As		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	41%	0%	0%	0%	0%	0%
Non-Specific																											
	FeOOH	5	0	0	1	1	1	0	2	0	1	1	1	3	1	1	2	1	1	3	2	1	0	1	0	0	3
	MnOOH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Phosphate	10	0	1	5	2	10	0	6	2	4	3	0	9	1	3	4	4	2	11	3	5	1	1	0	0	5
	Clay	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Non-Specific		16	0	1	6	4	11	1	8	2	5	4	1	13	3	4	7	5	3	14	5	6	2	2	0	0	8
% of total As		24%	0%	6%	10%	9%	22%	2%	26%	5%	11%	2%	1%	28%	2%	11%	10%	7%	23%	23%	10%	9%	4%	14%	0%	0%	62%
Total ASARCO Contribution		76%	100%	94%	90%	91%	77%	98%	74%	95%	92%	98%	99%	72%	98%	88%	90%	93%	77%	77%	90%	49%	96%	86%	83%	100%	31%	85%

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7.0 FURTHER STUDIES

The conclusions reached in this report are based on review of available data, which was primarily collected to protect the public health and not to determine the specific source(s) of a particular metal. Therefore, additional data should be collected that could aid in the final identification of the source(s) of lead and arsenic within the El Paso area soils. These data include: 1) more samples should be collected in the community, including sediment and interior dust samples. In particular, from the speciation results it is apparent that the areal limit of influence from the ASARCO facility is likely greater than the sample coverage.
2) speciation of sample sets for copper could also strengthen conclusions on source(s) and 3) a better effort to collect samples from the ASARCO facility which could give more specific information on the speciation characteristics of each of the metal circuits.

8.0 CONCLUSIONS

Based on the data presented in this report the following observations...conclusions can be reached with respect to the occurrences of lead and arsenic found in residential soils from the El Paso area.

- Arsenopyrite, PbAsO, and AsMO are the dominant arsenic contaminants in the soils
- Galena, anglesite, cerussite, phosphate, PbAsO, PbMO, and $PbMSO_4$ are the dominant lead contaminants in soils
- NO correlation between bulk lead and paint was found
- Greater than 53% of the bulk lead and 85% of the bulk arsenic can be apportioned to pyrometallurgical or concentrate sources

Based on the data reviewed in this report it is my opinion that the lead and arsenic in the El Paso area of study are the result of both smelter-stack emissions and fugitive dust from plant raw

materials.

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APPENDIX I

Table 1A. Site -Specific parameters for relative mass calculations.

	Specific Gravity	Pb mg/kg	As mg/kg
Clay	3.1	41900	5200
Anglesite	6.3	68400	0
AsCaO	6	10000	200000
AsFeOOH	4.5	46900	94600
AsMO	7	62000	184600
Arsenopyrite	6	0	460000
Barite	4	50000	0
Cerussite	6.6	776000	0
Cr	5	30000	0
CuM(SO,O)	6	40000	0
FeOOH	4	28500	3100
Galena	7.5	866000	0
MnOOH	5	150000	2800
Organic	1.3	20000	100
Paint	6	45000	0
PbAsO	7.1	500000	200000
PbAsVO	6.4	550000	5000
PbFeOOH	4.5	218000	44800
PbM(Cl,SO,O)	6.5	343000	26000
PbMSO4	5.7	368000	46000
PbO	9.5	930000	0
PbSiO4	6	500000	1500
Solder	6.3	73000	200
Phosphate	5	276000	10000
Pyrite	4	1700	15000
SbMO	6	50000	3000
Slag	3.6	1200	90
Sulfosalts	6	50000	50000
FeMSO4	3.7	51000	10000
BiMO	9	50000	500
Calcite	2.7	23000	200
Cu	8.9	1000	100000
CuMO	6	36000	15000
Native Pb	11.3	1000000	0